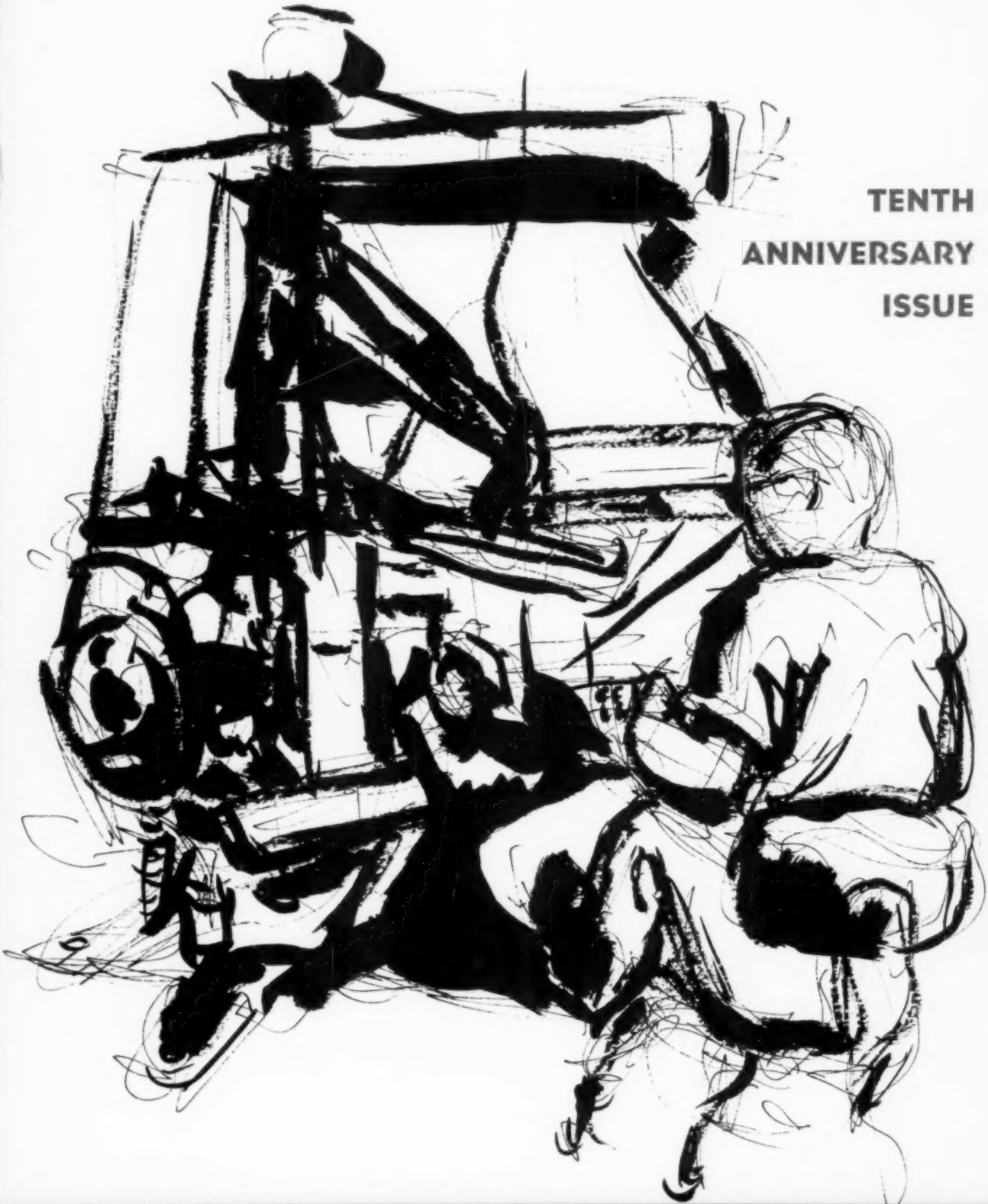
JOURNAL OF

METALS

JANUARY 1959



TENTH
ANNIVERSARY
ISSUE

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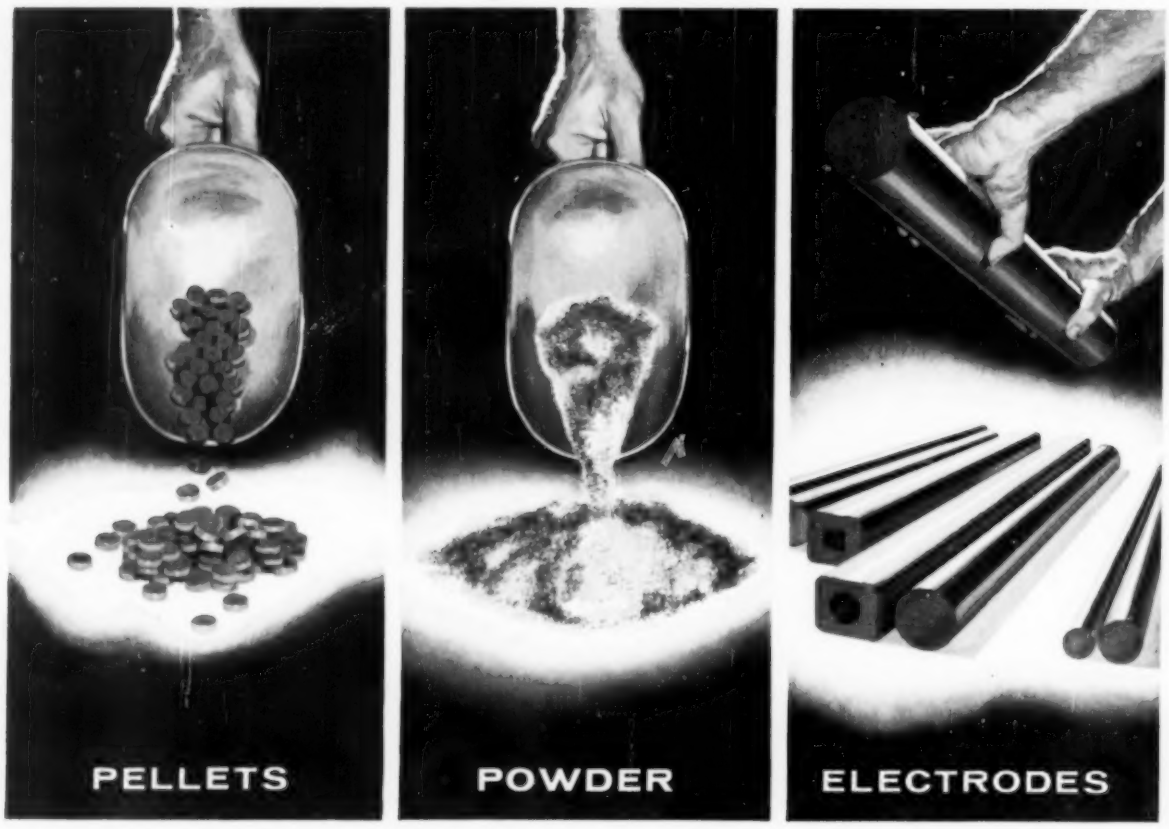

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JOURNAL OF

METALS

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Technical Writer with metallurgical experience, to prepare articles covering lead, aluminum, alloys, and powder metallurgy applications in nuclear and related fields for consultants. Salary, $7200-$8400 year. Location, eastern Pennsylvania. W6757.

Heat Treating Supervisor for nationally known manufacturer of precision instruments. Minimum of five years experience in comparable position with good working knowledge of metallurgy. Must be thoroughly familiar with furnaces and allied heat treating equipment. Apply by letter giving detailed resume. Location New York Metropolitan Area. W6750.

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(Continued on page 4)

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Personnel

Continued from page 2

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Plant Superintendent for foundry. Must have had experience in cast iron pipe by metal molds processes. Salary open. Company will negotiate placement fee. Location, New Jersey. W6816.

Writing Booklet

Technical Writing by Engineers by Michael K. Bonner gives a comprehensive review of the activity of engineers in writing articles and papers. Charts, graphs, plus comments from leading men in the field, back his suggestions for ways of obtaining articles from the working engineers.

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Metallurgical Equilibrium Diagrams, by W. Hume-Rothery, J. W. Christian, and W. B. Pearson, Oxford School of Metallurgists, illustrated, 311 pp., $10.00.

Creep of Metals, by L. A. Rotherham, M.Sc., F. Inst. P., illustrated, 80 pp., $3.45.

Constitution of Binary Alloys, 2nd. edition, Metallurgy and Metallurgical Engineering Series, by Max Hansen, *McGraw-Hill Book Co. Inc.*, 1305 pp., $32.50, 1958.—This revision and translation of the classic German work provides a source of reliable data concerning the constitution of binary alloy systems (phase diagrams) and the crystal structure of metallic phases. Here, widely scattered information in the world's metallurgical, physical, chemical, and crystallographical literature is analyzed and critically evaluated. This new edition has been prepared under the sponsorship of the United States Air Force through the Wright Air Development Center. •

The Effects of Radiation on Materials, Edited by J. J. Harwood and others, *Reinhold Publishing Corp.*, 430 Park Ave., New York 22, N. Y., 355 pp., $10.50, 1958.—Theories and concepts of radiation effects, radiation sources, and measurements of radiation are presented, as are the known effects of radiation on the physical, metallurgical, mechanical, corrosion, and electrical properties of materials. Among the materials dealt with are: metals, alloys, inorganic dielectrics, semiconductors, organic and polymeric materials, and materials for nuclear reactor components. Comprises papers delivered at Johns Hopkins University in 1957. •

Metal Statistics, edited by Norbert J. Langer, *American Metal Market,* 18 Cliff St., New York 38, N. Y., over 400 pp., $3.50, 1958.—Now in its 51st edition, this standard reference covers all of the important metals from aluminum and beryllium, to vanadium and zinc. Approximately one-third of the data deals with iron and steel. The volume also contains an index, and a valuable guide for buyers and sellers.

Reinhold Publishing Corp., 430 Park Ave., New York 22, N. Y., was recently appointed as sole distributor of the **Physics in Industry** • and **Monographs for Students** • book series of the Institute of Physics (London). There are seven Physics in Industry volumes now in print, and three Monographs for Students. They are as follows:

Physics in Industry Series

Pressure Measurement in Vacuum Systems, by John H. Leck, university lecturer in electronics, Dept. of Electrical Engineering, the University of Liverpool, illustrated, 144 pp., $5.50.

X-ray Diffraction by Polycrystalline, Materials, edited by H. S. Peiser, Hadfields Ltd., H. P. Rooksby, The General Electric Co. Ltd., and A.J.C. Wilson, University College of South Wales, 260 illustrations, 725 pp., $14.50.

Physics of Fibres, by H. J. Woods, senior lecturer on textile physics, University of Leeds, illustrated, 100 pp., $4.95.

Industrial Magnetic Testing, by N. F. Astbury, professor of physics, University College, Khartoum, 132 pp., $4.85.

The Measurement of Stress and Strain in Solids, based on proceedings of an Institute of Physics Conference, illustrated, 128 pp., $3.65.

(Continued on page 12)

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News of EDUCATION

► **North Carolina State College** has been given permission from the US Atomic Energy Commission to build a new reactor which will be used as a neutron source for reactor physics experiments, and for fundamental data on physics.

Housed in the Burlington Nuclear Laboratory, which is located on the campus of the College, the new reactor will be a graphite reflected, heterogeneous, water-moderated reactor designed to operate at a thermal power of 10 kw. The reactor is to be constructed by the Nucledyne Co. a division of Cook Electric Co., and is scheduled to be completed sometime between Oct. 1, 1959 and April 1, 1960.

► The **National Science Foundation** has awarded 377 grants totaling $12,796,007 for the support of basic research in the sciences, for conferences in support of science, for exchange of scientific information, and for the training of science teachers.

Recommendations for the awards were made by Dr. Alan T. Waterman, NSF director. The grants were in such varied fields as astronomy, biology, physics, earth sciences, engineering sciences, mathematical sciences, and the social sciences.

► The College of Mines of the **University of Arizona** has completed the new Geology Building, a wing of their Mines Building. The new facility will house the departments of geology, chemical engineering, and mining and metallurgical engineering, and have space for laboratories, classrooms, and faculty offces to accommodate undergraduate and graduate instruction. In addition, the Arizona Bureau of Mines office and laboratories, the regional office of the US Bureau of Mines, and the US Geological Survey Office, are furnished space in this modern new building.

► The **University of Washington** has taken over the operation of the former General Electric School of Nuclear Engineering at Richland, Wash. The school will now be called the University of Washington Center for Graduate Study at Hanford. Dr. Kermit B. Bengtson has been named director of the school which includes as co-participants the University of Idaho, Oregon State College, and Washington State College.

The school, which was started in 1948, had provided an opportunity for graduate training in the area of nuclear science and engineering to employees of the General Electric Co. and to others in the Richland area.

► Dr. J. W. Giachino, head of the industrial technology department of **Western Michigan University** has announced that the school is adding a two-year certificate program in foundry technology.

Gifts given through the foundry industry advisory committee have made the certificate program possible to a large extent, said Dr. Giachino. T. T. Lloyd, vice president, Albion Malleable Iron Co., Albion, Mich. is chairman of the foundry industry advisory committee.

► A new Summer Fellowship program for secondary school teachers has been announced by the **National Science Foundation.** Approximately 750 awards will be available for secondary teachers to undertake further study in the fields of science and mathematics.

An applicant for a fellowship must be a citizen of the United States, a science or mathematics teacher in secondary school, and have had at least three year's experience in that capacity. The applicant must have, in addition, a baccalaureate degree or its equivalent.

Applications should be made to the *Teacher Program, American Association for the Advancement of Science, 1515 Massachusetts Avenue, N. W., Washington 5, D. C.* All applications must be received by the Association by Jan. 19, 1959.

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► The Department of Metalllurgy of **Rensslaer Polytechnic Institute** has installed three vacuum-melting furnaces, together with extensive control facilities to make the institute one of the Nation's best equipped laboratories for study and research in the melting and fabrication of uranium, zirconium, and other metals of interest to nuclear technology.

The new equipment, purchased largely through a grant from the US Atomic Energy Commission and the Rochester div. of the Consolidated Electrodynamics Corp., is under the supervision of Wylie J. Childs.

One of the three furnaces is an induction furnace capable of melting 50-lb heats of uranium, steel, or other metals in a high vacuum. A large control panel in the center feeds the high-frequency power supply some 20 kw at 10,000 cps. The third unit in the group, the vacuum control panel, uses pneumatic force to open or close the valves and to regulate the vacuum.

The second furnace, constructed by the Heraeus Co., Hanau, Germany, and purchased from the Consolidated Electrodynamics Corp. is a consumable-electrode, vacuum arc furnace. The Heraeus furnace, is able to melt ingots up to 6 in. in diam. General Electric selenium rectifiers are provided to give the proper supply of current. Presently, Dr. A. A. Burr and his associates are using the Heraeus furnace for a study of zirconium in association with rare earths, under the sponsorship of the AEC.

Metals Society Honors Four At Recent Banquet

Three members of the AIME were among the recipients of awards for service and achievements in the science of metals given by the American Society for Metals. Dr. Albert J. Phillips, vice president and director of research, Americal Smelting Co., received the *gold medal* of the Society.

The medal for the advancement of research went to Crawford H. Greenewalt, president, E. I. DuPont de Nemours & Company. William G. Pfann, physical metallurgist, Bell Telephone Lab., Inc., was the recipient of the *Albert Sauver Achievement Award.*

Selected by the committee for honorary membership, was Ernest E. Thum editor-in-chief of the Society's journal, Metal Progress.

The awards winners were feted and honored at the Society's annual banquet which took place in Cleveland on October 30th.

Etching Manual

Atzheft, by Angelica Schrader, Fourth Edition, *Gebruder Borntraeger,* Berlin, Germany, 50 pp., $1.85, 1957—A manual on etching processes and solutions used in preparing metallic surfaces for metallographic inspection. The information is presented mainly in tabular form for efficient use. Included are brief special treatments of the differentiation of intermediate crystal types of aluminum alloys, electrolytic polishing, grain size of abrasives, etc.

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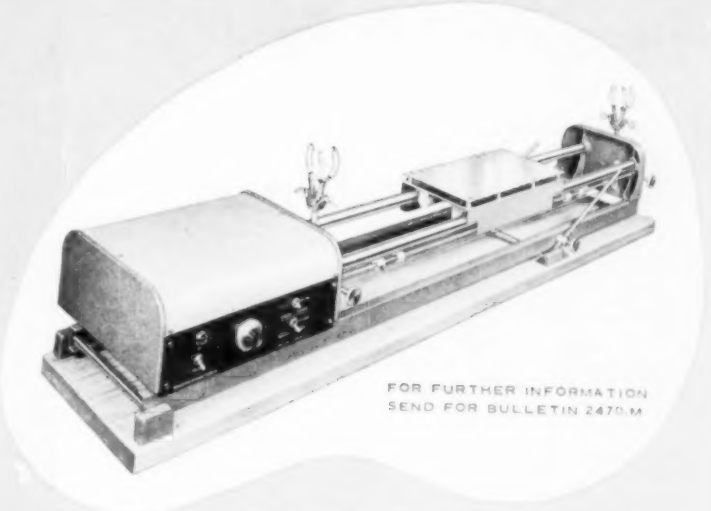

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EDITORIAL

The Second Year

AS The Metallurgical Society approaches its second anniversary, I should like to take this opportunity to discuss with you our progress during the past year and some of the problems we face in the future.

During our first year, President John C. Kinnear, Jr. and the Board of Directors faced the problems of a balanced activities budget, a publications policy aimed at fulfilling the needs of the Society on a sound financial basis, and an expansion of the technical committees designed to serve the needs of each individual member. With the effective coordination of the Society Secretary, Bob Shearman, and the hard work of J. S. Smart, Jr., A. W. Thornton, T. D. Jones, W. J. Harris, Jr., John Chipman, John Sullivan, and others, as well as a large financial assist from the Metals Research Publications Fund, these objectives were achieved.

At the start of our second year, the implementation of the new publications policy started with the publication of our new TRANSACTIONS on a bimonthly basis with an additional charge. Gerhard Derge was appointed as the new editor, and the printing of the TRANSACTIONS was changed from letterpress to offset. These changes may have been disturbing to some, but most members have shown a warm understanding of the efforts to publish **all** deserving technical papers in a **useful** format within our budget limitations.

The JOURNAL OF METALS in its 10th anniversary is aimed at developing into a publication for all the membership with a diversity of timely articles and news items. It is financed from dues, advertising, and outside subscriptions. A new approach to obtaining advertising is being organized to meet the expanding needs of this JOURNAL.

The activities of the Society were more extensive and diverse this year than ever before in the history of our divisions. The Secretary's office has been literally swamped with arrangements for special conferences and publications, in addition to our regular meetings, programs, and publications. The first independent all-Society meeting was held last fall in Cleveland, when all three divisions joined together for technical sessions during the Metal Congress. A new local section associated with the Society was formed in the Hudson-Mohawk area. The expansion of the technical committee framework described elsewhere in this issue, required additional staff assistance in Bob Shearman's office.

This second year, it is anticipated that our budget will be balanced as a result of a fine response of subscriptions to TRANSACTIONS, non-member subscriptions to JOURNAL OF METALS, and the assistance from the Metals Research Publications Fund, smaller in amount than in the previous year. This is real progress.

It has become evident, however, that to finance our expanded publications, programs, and activities, it will be necessary to increase the advertising in the JOURNAL, to increase the number of subscriptions to TRANSACTIONS and, most essential, to increase the Society's membership.

Changes in publications and technical committee structure should appeal to a much broader range of the metallurgical profession. Our new Assistant Secretary, Doug Johnston, is working with our Membership Chairman, D. C. Hilty, in planning an extensive organized drive for new members. We hope to expand eventually from our present number of about 6800 to the estimated potential of over 10,000 metallurgists actively engaged in our profession. This activity is one of the most critical problems facing our Society.

I should like to thank, publicly, all the people who have contributed to our successful operation during this second year through untiring hard work on committees and participation in our activities. Will those who have suggestions for improvements, please let me know about them, and bear with us while our Society progresses through these *shakedown* years. Help us to obtain new members from among your qualified associates. Continue to support our publications and activities next year under the leadership of John Chipman in the same wonderful way you have supported me this year. This is the way to continued success.

Walter R. Hibbard, Jr.
President,
The Metallurgical Society of AIME

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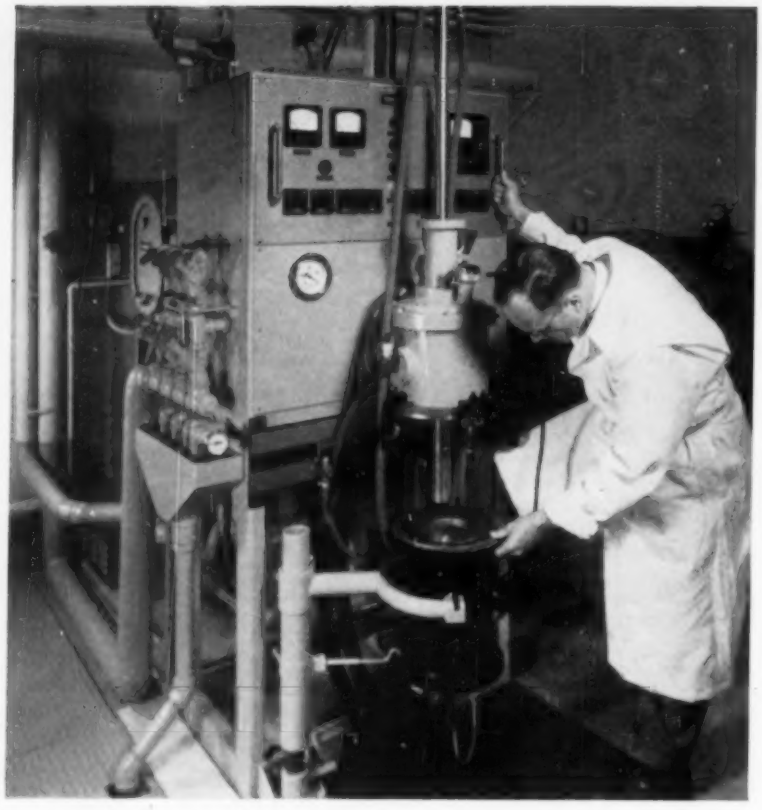

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SALES AND SERVICE OFFICES IN PRINCIPAL CITIES

Books

(Continued from page 7)

Errors of Observation and Their Treatment, revised edition, by J. Topping, principal, Action Technical College, London, paperbound, 121 pp., $1.50.

Theory of Lenses, by E. W. H. Selwyn, Research Laboratories, Kodak Ltd., paperbound, 64 pp., $1.20.

Soft Magnetic Materials Used in Industry, by A. E. DeBarr, senior scientist, Elliott Brothers Ltd., paperbound, 64 pp., $1.20.

Bibliographic Survey of Corrosion, 1954-1955, by the *National Assn. of Corrosion Engineers*, 1061 M&N Bldg., Houston 2, Texas, 468 pp., $20.00, 1958.—A thorough review of corrosion literature for the period covered. Substantial abstracts of papers cited are arranged in eight major divisions: general, testing, characteristic corrosion phenomena, corrosive environments, preventive measures, materials of construction, equipment, and industries. Author and subject indexes are included.

Thermal Properties of Thirteen Metals, by C. F. Lucks and H. W. Deem, special technical publication no. 227, *American Soc. for Testing Materials*, 1916 Race St., Philadelphia 3, Pa., 29 pp., $1.25, 1958.— Presents the results of a study conducted by the Battelle Memorial Institute to determine the following properties: thermal conductivity, thermal expansion, specific heat, density, and thermal diffusion. Aluminum, chromium, copper, Inconel, magnesium, molybdenum, and several steels are among the metals covered.

Story of The Second World Metallurgical Congress, edited by Kingsley W. Given, *American Soc. for Metals*, 7301 Euclid Ave., Cleveland 3, Ohio, 225 pp., $5.00, 1958.—A brief account is given of the study tours and group discussions held in connection with this congress, held in October-November 1957. It includes a list of overseas conferees by countries and of American conferees arranged by interest groups.

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Scientific Papers, Vol. I: Mechanics of Solids, by G. I. Taylor, edited by G. K. Batchelor, *Cambridge University Press*, 32 E. 57th St., New York 22, N. Y., 593 pp., $14.50, 1958.—This first volume contains all of Taylor's studies on the mechanics of solids. It includes papers on elasticity, plasticity, the properties of metals, and the famous work on dislocation theory. A number of papers (written for government depts. or advisory committees are here made generally available for the first time. Subsequent volumes (there will probably be four in all) will contain papers on meteorology, oceanography and turbulent motion of fluids; high speed flow and mechanics of explosions; and miscellaneous topics in fluid dynamics.

U. S. Department of Commerce Publications

Request publications from:

Office of Technical Publications

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PB 121953 *Investigation of the Creep-Rupture Properties of Mo-V Low-Alloy Steels,* by P. Shahinian and J. R. Lane, Naval Research Laboratory, 75¢, 23 pp., 1957.

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Titanium future brightens

Still in the specialty metal category, signs point toward titanium heading into the tonnage metal group, says Battelle Memorial Institute's Defense Metals Information Center in a memorandum, "Recent Advances in Titanium Technology." Mach 3 airplanes with titanium alloy structure may soon be flying; solid propellent rockets with titanium alloy cases will probably be built; welded, heat-treated titanium alloy helium bottles will fly with the Atlas ICBM. For report on new titanium alloys, see p. 29.

Metal forming by explosion

Recent tests indicate that almost any metal—including those formerly regarded as too brittle—may be formed by explosive methods. Among the firms interested are Convair, Olin Mathieson, Du Pont, Union Tank Car, American Potash, North American, Chromalloy Corp., and Aerojet-General Corp. In Aerojet's test, blank metal to be formed is fastened above bowl-shaped portable metal mold backed in concrete. Explosive charge is suspended above the blank, and the entire unit is submerged in a tank of water. Detonation transmits pressure through the water, forming the metal blank to the mold's configuration. Pressures from a few psi up to more than one million psi may be directed and controlled by proper wave-shaping of explosives.

Ultrasonic welding

An ultrasonic seam-welding process has been announced by Westinghouse Electric Corp. Metals to be welded are passed between two wheels connected to ultrasonic transducers, causing a binding by intermolecular forces. The experimental welder has been used successfully to seam-weld thin sheets of steel, copper, silver, and certain alloys . . . Aeroprojects Inc., of West Chester, Pa., which specializes in ultrasonic apparatus, has developed a force-insensitive transducer coupling device, and reports successful welding of structural aluminum alloys in thicknesses up to 0.064 in. Their largest spot welding unit at present has a 4000 watt capacity.

New production and research facilities

Construction holds the spotlight in Ariz., Pa., and Conn. Kennecott Copper Company's 20,000 ton-per-month copper smelter was dedicated recently in Hayden, 65 miles north of Tuscon. The smelter is capable of producing 700-lb anodes, 99.95 pct pure copper . . . Construction of a $4 million metallurgical research center for Olin Mathieson Chemical Corp., in New Haven, will be completed by mid-1959. The laboratories will provide research, development, and integrated pilot plant production facilities and services for metals and nuclear activities . . . Final contracts have been placed for the construction of the IN-FAB (inert fabrication) plant by Universal-Cyclops Steel Corp., in Bridgeville, Pa. Primary concern of the new plant, to be completed in one year, will be the fabrication of molybdenum and other alloys within their true working temperature range in an inert atmosphere.

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ELEMENTS OF PHYSICAL METALLURGY, Second Edition

by ALBERT G. GUY, *Purdue University*

This is the new second edition of a widely used textbook for introductory courses in physical metallurgy. The principal features of the revision are: (1) introduction of dislocation theory; (2) addition of material on electron theory of metals, in view of the increased importance of electronic phenomena in semiconductors; (3) introduction of a new chapter, *Phases in Metals Systems*, to prepare the student for the study of phase diagrams in the following chapter; (4) addition or revision of material required to bring the book completely up to date. As was the case with the first edition, a balance between theory and practice has been maintained.

c. 576 pp. 297 illus, Second Edition 1959—$9.50

FUNDAMENTAL ASPECTS OF REACTOR SHIELDING

by HERBERT GOLDSTEIN, *Nuclear Development Corporation of America*

This new book by the author of the distinguished *CLASSICAL MECHANICS* is, in essence, a revision of the book *THE ATTENUATION OF GAMMA* RAYS AND NEUTRONS IN REACTOR SHIELDS which Dr. Goldstein prepared at Nuclear Development Corporation of America for United States Atomic Energy Commission. It will be of keen interest to physicists, biologists, health physicists, chemical, mechanical, and nuclear engineers—in a word, to all who are concerned with reactor and shield design. The twofold aim of the work is to encourage further investigations into the basic physics of shields, and to supply an exposition of the fundamental shielding processes, which serve as the basis for design of any reactor shield. The author concentrates on the "fundamentals"—the factors affecting the permissible radiation levels, the sources and characteristics of the radiation to be shielded against, how bulk shielding measurements are made and, at greatest length, how the attenuation of neutron and gamma rays in shield materials is calculated, theoretically or empirically.

400 pp. 95 illus, 1959—$9.50

CONSTITUTIONAL DIAGRAMS OF URANIUM AND THORIUM ALLOYS

by FRANK A. ROUGH AND ARTHUR A. BAUER, *Battele Memorial Institute*

Written in cooperation with United Kingdom scientists and engineers, this valuable compilation of U.S. and U.K. uranium and thorium constitutional diagrams is a compact and highly useful source of reference material for all working in the field. It is divided into two major sections, uranium alloys and thorium alloys, each preceded by a discussion of the transformation and melting temperatures of the base metal. The various systems are listed in alphabetical order, including both binary and ternary systems.

153 pp. 72 illus, 1959—$5.00

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Celebrating JOURNAL OF METALS' TENTH YEAR

Yes, with the January 1959 issue we are just 10 years old. But not many now on the staff can remember that far back in the history of JOURNAL OF METALS; *so, we devised a new title, Historical Editor, and sent our man climbing through the dusty records of the past. We learned a lot of things about ourselves . . . and pass them on to you . . .*

At the regular meeting of the AIME Board of Directors in November 1947, a committee was selected and instructed to perform a comprehensive study of all AIME publications, including *Mining and Metallurgy,* the Technologys, the Transactions, and the Proceedings of the two conferences sponsored annually by the Iron and Steel Conference Committees.

In its report, which came to be known by the name of its chairman, Hjalmar Johnson, the Committee suggested that publication of Transactions and Technologys, in their then present form, be discontinued. In place of these, appropriate new journals should be developed for the mining, metals, and petroleum branches. The contents would be substantially the same technical papers appearing in the Technologys.

One year later, JOURNAL OF METALS, MINING ENGINEERING, and JOURNAL OF PETROLEUM TECHNOLOGY were established as separate publications. This was a marked improvement over the previous publications, which had sought to present articles on all phases of engineering pertinent to AIME. The technical papers, or *transactions* sections, of each journal were overprinted and bound annually as AIME Transactions volumes, preserving the continuity of publications under this label. Bound volumes of transactions had appeared since 1873, although individual technical papers had been available as pre-prints.

The first bound volume, *Transactions of the AIME,* was adequate for its day. The *AIME Bulletin* (estab. 1905) and *Mining and Metallurgy* (estab. 1919) recognized the growth of the organization and the diversification of interests in the field.

Until 1927, all papers eligible for Transactions were brought out in general volumes. During that year, in an attempt to reduce the amount of material sent to each member, the general volume was abandoned in favor of segregated volumes published at regular intervals. At the same time, Technical Publications were issued separately so that a member wishing articles within a certain classification would not be burdened with *extraneous* material.

A further step toward literary autonomy was taken in 1934 with the creation of *Metals Technology.* This consisted of current technical papers sponsored by IMD. So satisfactory was this experiment that three other journals sprang up during the next 12 years (*Mining Technology,* 1937; *Petroleum Technology,* 1938; and *Coal Technology,* 1946).

As the Johnson Report recognized, the continual creation and abolishment of pamphlets, magazines, and reports over the years, although momentarily helpful, did not establish literary stability in the engineering field. The one exception to this was the previously mentioned bound volumes of Transactions. When the suggestions of the three-member committee were put into effect ten years ago, it was felt, by and large, that AIME had *finally* adopted a publication policy consistent with the growth of the organization.

Manchester, N. H., home of the Journal of Metals. Engravings are made at the Hampshire Engraving Corp., shown at left. They join the printed word set on the linotype machines of Lew A. Cummings Co. At lower left, "Kit" is shown assemblying the finished pages. Printing, shown at lower right, is followed by binding, trimming, and addressing prior to delivery to the homes and offices of our readers.

But *finally* was to be temporary. In 1958 The Metallurgical Society Publications Committee brought about another change. Chairman William Harris, Jr., wrote in an explanatory editorial: "In recognition of the desire of many members to have science and engineering technical papers combined, and in recognition of the need for a scheme that appeared consistent with our financial capabilities, a program of publication based on two journals was finally accepted. One of these journals will be the JOURNAL OF METALS. Subject matter will include papers on professional and economic subjects, review and summary articles in metal science and engineering, abstracts of technical papers to be presented at regular meetings of the Society, and discussions of the broad problems of concern to all members of the Society.

"The second journal will be called *Transactions of the Metallurgical Society of AIME*. In this journal will be presented technical papers on subjects in the fields of metal science and metal engineering."

Thus was created the JOURNAL OF METALS as you read it this month. It is not a magazine of chance discovery; rather it is the latest development of 86 years of AIME publications.

The information media of this Society must keep abreast of the Society's expansion. It is to be hoped that for many years to come, JOURNAL OF METALS, now entering its 11th year of publication, will continue to serve as the voice of metallurgy throughout the profession.

The Present

And after that excursion through the distant and immediate past, we would like to carry you on to the present . . . today . . . the five eager faces that tear your manuscripts to pieces and put them together again. Here is how this miracle is performed!

The average citizen, upon seeing an article in the morning newspaper which pertains to a new development in the field of metallurgy, may be expected to skim through the paragraphs, perhaps tuck away the information in a vacant section of his mind, and then settle down to the financial section or the crossword puzzle. In other words, the average citizen takes metallurgy for granted; he knows there are metallurgists scattered here and there around the world (although he may not know why), and he expects periodic developments in keeping with the purpose of the profession.

In the same manner, our readers may be excused if they pick up each month's issue of JOURNAL OF METALS, peruse the feature articles, take note of the monthly departments, and put down their copy without realizing the months of work that go into each issue.

Because JOURNAL OF METALS is as much your magazine as ours, and because it is published for you rather than for the staff members, we wish to

In New York City at the Engineering Societies Building on 39th Street, plans for future issues are worked out, copy is edited, illustrations are processed, and page layouts are done. Above, Starratt and Van Cronkhite planning. Top right, Camile Cardon working. And bottom right is production editor, Otto Johnson, who handles relations with printer and engraver. James Burke, just returning from military service, is also one of us.

show you in words and in pictures how your papers are processed, how the monthly departments are compiled, how cooperation from metallurgist to printer produces the monthly journal you are now reading.

From metallurgist to printer

The nucleus of the magazine is the five-member editorial staff located at AIME headquarters. The managing editor, a graduate metallurgist and economist, plans out future issues, maintains control of copy, and later works out page layouts. Papers submitted for publication receive his attention prior to being placed in the hands of the editorial staff.

An editor, in the opinion of some authors, is an Artzybasheff creation—one part blue pencil, one part intense dislike for all authors. In reality, an editor rarely connects a personality with a manuscript and usually he avoids using the editing pencil wherever possible. It is his function, however, to see that each manuscript reflects uniform punctuation and clarity of sentence structure.

Preparing the average manuscript for printing requires reading and rereading as well as careful consideration of what illustrations and tables would best help in understanding the subject matter and conform to the allotted number of magazine pages. The article must be edited, keeping in mind the policy of brevity and clarity of text. After retyping, the manuscript is finally ready for the printer.

Galley proofs from the printer are checked by the editorial staff and forwarded to the author for further consideration. Because of the expense involved in resetting, type changes are kept to a minimum.

Information used in the *Reporter, AIME News, Necrology,* and other monthly departments, is edited in the same manner as the feature articles.

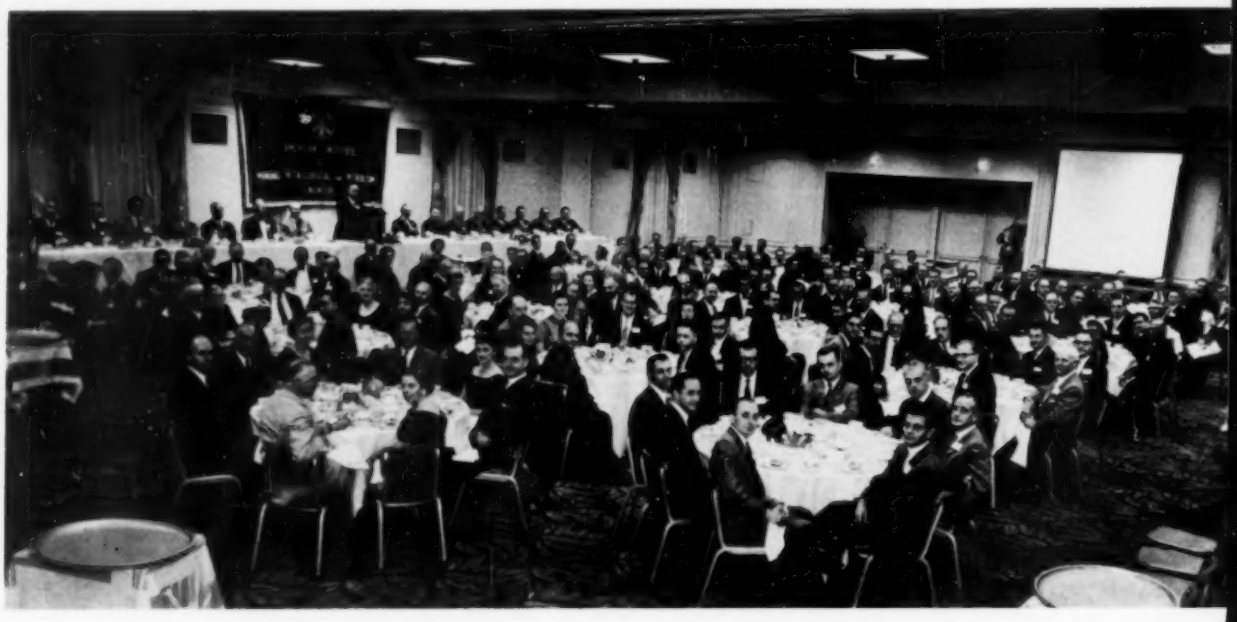
Advertising, an important part of the magazine, is prepared as far in advance of the publication as possible. A two-man staff at AIME headquarters, working with agencies and salesmen throughout the US, confirms advertising contracts and passes along the copy to the magazine production editor, who arranges the layout in coordination with the articles.

JOURNAL OF METALS is printed by the Lew A. Cummings Co. Inc., in Manchester N. H. Pictures and drawings are engraved on magnesium plates by the Hampshire Engraving Corp. also in Manchester. Type and engravings join at the Cummings plant where they are assembled into pages, printed, bound, trimmed, and mailed out to you.

The finished magazine is the result of approximately two months of research, editing, proofreading, layout planning, and writing. Each issue is the product of co-ordination among authors, editorial staff, the printer, the engraver, the advertising department, and the AIME staff. JOURNAL OF METALS, in its entirety, is a complex organization requiring varied skills, exact timing, and above all, cooperation.

One hundred and twenty-one deadlines ago, JOURNAL OF METALS went to press for the first time. In the first editorial, Frank T. Sisco, then director of Alloys of Iron Research, set down two goals for the magazine: facts and brevity. Ten years have passed since the writing of that editorial, and our objective has not changed from Mr. Sisco's concise appraisal.

ALL-OUT PARTICIPATION IN THE FALL MEETING OF THE



This year the former IMD Fall Meeting had a new name, the *Fall Meeting of The Metallurgical Society*, sponsored by IMD. While the 1957 Fall Meeting included participation by the Iron and Steel Div. as well as the Institute of Metals Div., this year, for the first time, the meeting had technical sessions by all three divisions. There were four simultaneous technical sessions from Monday morning through Thursday noon. Registration began on Sunday, October 26th, and continued until the end of sessions on Thursday, October 30th.

The **Iron and Steel Div.** arranged two sessions which featured reports by American metallurgists who recently visited steelmaking plants in the Soviet Union. At the morning session, speakers reviewed raw materials, blast-furnace and coke-oven operations, open hearths, and electric furnaces. The afternoon session included talks on Soviet rolling mills, vacuum techniques, and steelmaking research, thus completing a full coverage of current Soviet development in the ferrous metals field. JOURNAL OF METALS published J. H. Strassburger's paper, *Soviet Blast Furnace Practice*, on p. 721 of the November 1958, issue, while a paper by K. C. McCutcheon on *Open-Hearth Shops of the USSR* also appeared in the same issue.

The **Extractive Metallurgy Div.** participated in the Fall Meeting for the first time. Two sessions were held by the EMD Physical Chemistry of Extractive Metallurgy Committee: the first a symposium, *Physical Chemistry of Halide Systems*, and the second, *New Applications of the Phase Rule in Extractive Metallurgy*.

The **technical committees of IMD** sponsored a number of sessions. Among them was the Semiconductors Committee, which held its first technical sessions—*Government-Sponsored Research on Semiconductor Metallurgy*. The technical session was followed by a general luncheon under the sponsorship of the Committee.

The IMD Chemistry and Physics of Metals Committee sponsored two session: *Point Imperfections* and *Effects of Small Dimensions*. A review of both is included on p. 23 of this issue.

The Seventh Annual Titanium Symposium, sponsored by the Titanium Committee of IMD was held on Tuesday morning and afternoon. Panels discussed such diverse subjects as price, quality, prospects, new processes, etc. The afternoon panel, *New Alloys*, moderated by R. I. Jaffee, is reviewed on p. 29 of this issue.

The IMD Powder Metallurgy Committee conducted its annual symposium with papers presented on high-purity tantalum, molybdenum-nickel dispersion alloys, titanium carbide, and carbonyl iron. Werner Leszynski reviewed the Third International Plansee Seminar held in Reutte/Tyrol, Austria; his paper on p. 24 of this issue. At the general

METALLURGICAL SOCIETY OF AIME

Highlight of the Fall Meeting was the Annual Dinner, shown on opposite page. Edward Mapes, Chairman of the Cleveland section of AIME welcomed all to industrial Cleveland (above). Later (above right) J. H. Hollomon was presented with the 1958 Rosenhain Medal by R. A. Wilkins on behalf of the Institute of Metals (of the UK). An honored guest (lower right) at the Dinner was K. Headlam-Morley, Secretary of the Iron and Steel Institute (of the UK).

luncheon following the morning symposium, a report on powder metallurgy discussions at the Second UN International Conference on the Peaceful Uses of Atomic Energy was given by Henry H. Hausner; this report is published on p. 36.

Highlight of the Fall Meeting of The Metallurgical Society was the Annual Dinner held on Tuesday evening, October 28th. Toastmaster was O. T. Marzke, vice president, Fundamental Research, US Steel Corp. Edward Mapes welcomed all to Cleveland on behalf of the Cleveland section of AIME. President of the American Society for Metals, George Young, expressed the "hope that our two societies will continue to cooperate with each other, for there is much that we can do together for society and industry."

J. H. Hollomon was presented with the 1958 Rosenhain Medal by R. A. Wilkins, vice president of Revere Copper & Brass. The Award is made annually by the Institute of Metals (of the UK) and bestowed on individuals who have made outstanding contributions in the field of metallurgy. Said Dr. Hollomon upon receiving the award, "I believe that awards are given for two purposes: to honor and to set standards. I sincerely hope I deserve the honor." Attendance of Kenneth Headlam-Morley, Secretary of the Iron and Steel Institute (of the UK), contributed to the success of the evening. He com-

mented, "I think Dr. Rosenhain would have been pleased that the medal went to a man who lived up to the criteria of his beliefs."

Walter R. Hibbard, Jr., President of The Metallurgical Society, and Augustus B. Kinzel, President of the AIME, were also present on the dias. They expressed greetings and offered best wishes to all for a most successful meeting.

Speaker of the evening was George B. Woolard of the Dept. of Geology, University of Wisconsin. Dr. Woolard spoke on the results of the International Geophysical Year in the Antartica studies.

Metal Show Highlights

Running simultaneously with the Fall Meeting of The Metallurgical Society of AIME, was the 40th National Metal Show of the American Society for Metals at the Cleveland Public Auditorium.

Theme of this year's Metal Show, *Make It Better With Metals . . . for Less*, attracted an attendance of more than 60,200. A pageant of metal progress . . . a number of firsts in new metal products and techniques . . . were shown in the 406 exhibits.

Zirconium and Zircaloy-2 samples made by a new continuous process were shown by the Titanium div. of National Lead Co. This process produces a continuous metal compact directly from zirconium tetrachloride in one operation. The compact is cut into desired lengths for consumable electrodes which are arc-melted without further treatment. Claimed for this process are: lower costs, higher purity, and greater uniformity. The hydrogen content of the metal is less than 10 ppm, oxygen in the range of 200 ppm, and 20 ppm of nitrogen, all much lower than conventionally produced metal.

Alco Products, Inc. showed machining operations of its cost-saving leaded steel. At its Latrobe, Pa. plant, the firm manufactures Hi-Qua-Led steel forgings which maintain all the physical characteristics of regular steels, while making possible greatly reduced machine time, longer tool life, and improved surface finish.

F. J. Stokes Corp. showed its new cold-wall vacuum furnace for sintering at 4000°F. Sintering of powder metal parts compacted of materials with a very high melting point such as tantalum, and degassing of components such as tungsten elements for electronic tubes (which require equally high temperatures), are both practicable in the new furnace. This vacuum furnace is suitable for experimental work and for small scale production. Within its vacuum retort, which is 20 in. in diam and 20 in. deep, is a resistance-heated hot zone 3½ in. in diam and 6½ in. deep. This is surrounded by a multi-layer reflective shield which, in turn, is surrounded by a water jacket.

As the first example of rolled, extruded, and drawn products of high-purity, ductile vanadium highlighted the exhibit of Vanadium Corp. of America (see JOURNAL OF METALS, September 1958, p. 618). Other new developments included a series of high-chromium alloys with extra low carbon content. The new alloys, under the trade name of EXLO "75", contain a minimum of 75 pct Cr and a maximum of 0.015 and 0.25 pct C. They are designed to reduce the tonnage of alloying agent to be handled, as well as to minimize chilling of metal in the ladle, and lessen the need for removal of carbon by extended furnace operation.

A 330-lb columbium ingot, measuring 9 in. in diam and 19 in. in length, was on exhibit by Electro Metallurgical Co., div. of Union Carbide Corp. The metal was produced in the form of roundels by Electromet and consumable-arc melted by the Refractomet div. of Universal Cyclops Steel Corp. This joint venture was undertaken to investigate the feasibility of producing larger columbium ingots on a commercial scale.

Haynes Stelite Co., div. of Union Carbide Corp. displayed parts made from tantalum, silicon nitride, and metal-ceramics. A special feature was a 30-gallon chemical reactor vessel completely lined with tantalum. Parts of silicon nitride included large crucibles and boats such as those being considered for use in zone refining of transistor-grade metals.

These exhibits were only a few of the highlights of this mammoth show which we spotted while walking through the labyrinth of passageways and halls that is the Cleveland Auditorium. Many other exhibits had a high level of professional interest, and we regret our inability to mention more of them.

Cleveland, Ohio—site of the Fall Meeting and the Metal Show.

Fall Meeting: Metals Behavior

In two symposia that were presented by the Chemistry and Physics of Metals Committee at the Fall Meeting, many new scientific techniques and facts were presented by six outstanding lecturers.

Point Imperfections

An audience of 150 heard J. W. Corbett of the General Electric Co., C. A. Wert of the University of Illinois, and A. S. Nowick of the IBM Watson Laboratory, discuss various means of producing and studying point imperfections, and joined in spirited discussion of each paper.

Corbett described the production of interstitial atoms and lattice vacancies in copper by electron bombardment. The presence of these products of radiation damage can be detected by measurements of electrical resistivity. A study of the change in resistivity with time and with temperature on heating from an initial irradiation temperature near absolute zero, makes possible an identification of the nature of the damage. Briefly, Corbett showed how it was possible to identify close interstitial-vacancy pairs and free interstitial atoms in the irradiated material. The interstitial atoms moved about in the material at a temperature of 40°K. They could be trapped at impurity atoms in the copper or be annihilated by meeting a vacancy.

Wert reviewed the techniques of internal friction, whereby through mechanical relaxation measurements it is possible to measure the diffusion rates of point imperfections in crystals. He discussed the diffusion of interstitial atoms in body-centered cubic metals, such as chromium. Not only is it possible to study diffusion by means of internal friction, but it is also possible to study the interactions between impurity atoms in a solid solution. Wert described the results of experiments which helped to clarify the interactions between interstitial atom pairs, between interstitial atoms and substitutional impurities, and between impurity atoms and dislocations.

Nowick discussed the production of vancancies by heating a crystal, allowing the equilibrium concentration of vancancies to build up, and quenching the sample to retain this concentration at low temperature. He pointed out the dangers of using thermal expansion measurements to estimate the vacancy concentration at high temperatures, and outlined other more reliable means, based upon measurements of electrical resistivity.

Nowick showed that it was possible to measure the energy of formation of a lattice vacancy by measuring the relative concentrations of vacancies quenched in from different high temperatures. He showed that the activation energy for moving a vacancy could be estimated from the kinetics of vacancy annealing. The sum of these energies checked well with the measured self-diffusion results. Most metals appear to have roughly one vacancy per thousand atoms at the melting point. An unsolved problem is the apparent reluctance of vacancies to unite in pairs during quenching.

Small Dimensions

N. Cabrera (University of Virginia) spoke on *Properties of Whiskers*. He suggested that the growth of a whisker from a vapor or a solution is dependent upon impurity atoms; if there are no impurities, growth should soon stop because the steps on the side of the whisker should disappear. He discussed the considerable experimental evidence that now exists for the presence of screw dislocations parallel to the whisker axes: tilt of Laue spots from individual whiskers, the appearance of etch pits and, even more directly, decorated dislocations in whiskers of transparent, non-metallic substances. Additional data on the tensile strength of whiskers show that their strengths increase rapidly as the whisker diameters decrease.

The Mechanical Properties of Thin Films were described by J. W. Beams (University of Virginia). Beams and his students have measured the strengths of metal films by depositing them electrolytically onto small cylindrical rotors, which are then spun at high speeds until the films break off. Silver films tested in this way show a sudden increase in strength when the film thickness decreases below about 2500 A. Films much thinner than this are so strong that the rotors explode before they reach a speed that is large enough to break the films. Thinner films can be tested by a *bulge* method, in which the film, fixed to the end of tube, is bulged out by the pressure of air in the tube. In bulge tests the strength increases suddenly at 1000 to 1500 A. Work is now in progress on single-crystal films, made by depositing the metal onto silver chloride crystals.

The final lecture was given by C. P. Bean (General Electric Research Laboratory) on *Magnetic Properties of Whiskers, Thin Films, and Small Particles*. Just as it is difficult to produce slip in a whisker, it is also difficult to nucleate a domain of reversed magnetization in a fully magnetized whisker. Once they are nucleated, however, the domain walls can travel along a whisker at very high velocities—up to Mach 5 in iron. The magnetic properties of thin films are of current interest because of their possible use in computers: they have square hysteretic loops and can be *switched* very quickly from one direction of magnetization to the other.

There is much interest in fine particles. Particles which are so small in all dimensions that they contain no domain walls, undergo reverse magnetization only with difficulty. Therefore, such particles make good permanent magnets when they are compacted with a suitable binder. As the particle size decreases, the coercive force reaches a maximum (at about 50 A. for iron) and then decreases, because the particles are then so small that thermal fluctuations begin to throw the electron spins out of alignment. This has been termed super-paramagnetism.

POWDER METALLURGY DEVELOPMENTS

Two international meetings held in Europe during 1958 brought forth new ideas and developments in the field of powder metallurgy. The papers presented at these gatherings have been summarized by two experts.

The two papers making up this article were presented at the Fall Meeting of The Metallurgical Society. Werner J. Leszynski talked on the Third International Plansee Seminar, held at the Metallwerk Plansee in Reutte/Tyrol from June 22nd to June 26th of 1958. At the general luncheon sponsored by the IMD Powder Metallurgy Committee Henry H. Hausner discussed powder metallurgy at the UN Atoms-for-Peace Conference in Geneva.

International Plansee Seminar

by Werner J. Leszynski

Production, properties, and applications of high-melting metals were discussed at the Third International Plansee Seminar, held in Reutte/Tyrol, Austria, in June 1958.

Tungsten

Recrystallization mechanism and sub-structure of tungsten wire was investigated by G. A. Geach and F. O. Jones[1], J. W. Pugh[2], and G. D. Rieck[3]. The British authors discussed two types of sub-grain structures which can be revealed by the use of several etchants. Pugh gave approximate temperature ranges for the disappearance of vacancies and interstitials, the annihilation of dislocations, polygonization, sub-grain growth, and recrystallization. Rieck discussed, in particular, the recrystallization in *doped* wire, presenting a concept of growth which explained the lining-up of the additions in the form of strings, as well as the change of texture due to the *dope effect*.

R. Bernard[4] demonstrated a relation between the microstructure of tungsten and its suitability as a contact material for low-voltage circuit breakers (6 to 12v, 0.2 to 1a per mm^2). For contacts cut from rolled or swaged bars, a very fine long-fibered structure appears essential for satisfactory performance.

D. A. Davies[5] presented a reappraisal of theory as well as a practice of the so-called flash-test for tungsten wire. This is used widely in the industry and consists of a selected capacitance. The test is extremely sensitive to variations in resistivity, but it is not sensitive to variations in surface conditions. Life tests are in agreement with flash-testing data.

R. I. Jaffee, C. T. Sims[6], and J. J. Harwood[7] investigated the effect of rhenium on tungsten and found that the transition temperature is lowered by the addition of rhenium, but not as much as with molybdenum. Consequently, low temperature ductility is not achieved. However, the addition of about 30 pct Re substantially aids tungsten hot workability.

H. Braun, R. Kieffer, and K. Sedlatschek[8] systematically studied the technology of W-Ta alloys. Density, lattice parameters, hardness, modulus of elasticity, electrical conductivity, and resistance to oxidation were determined. It was found that dense-sintered materials of all compositions could be obtained by a two-stage process: first, preforming the solid solutions in a sintering process and then crushing and grinding the compacts; second, recompacting and resintering the preformed solid solutions. Alloys containing up to 30 pct W were found to be ductile at room temperature. Alloys having up to 20 pct Ta were hot-workable, while alloys with 20 to 70 pct Ta were not workable. Of practical interest is the 80-20 Ta-W composition, which is resistant to attack by 20 pct HF and workable.

An important application of tungsten is its use as a rotating target for X-ray tubes, which can survive overloading with more or less pronounced fluctuations. The X-ray output generally decreases with time, due to changes in the surface structure of the focal area.

According to R. Griffoul and A. Schram,[9] this aging can be minimized by reducing the maximum temperature of the target; such cooling may be effected by carburization, the tungsten carbide formed having a higher thermal emissivity than the parent metal. Carburization is accomplished by vapor-decomposition of hexane. It is preferable that the focal area itself remain uncarburized. This is achieved by covering the area with a rhenium-coated molybdenum ribbon during the carburization treatment. Rhenium forms no carbides and acts as catalyst for the hexane decomposition. An advantage of carburized targets is the reduction of extra-focal radiation which impairs the quality of radiographs.

Tantalum

The oxidation mechanism of tantalum was discussed by G. Brauer, H. Müller[10], and E. Gebhardt[11]. Brauer and Müller found that Ta_2O and another suboxide (probably Ta_4O) are formed upon exposure of fine tantalum powder in air at 330°C. Gebhardt reported that in oxygen, a leaflet-shaped phase is formed in addition to the Ta_2O_5 scale. These leaflets grow from the surface of the specimen into the Ta-O solid solution and markedly decrease the ductility in bending without decreasing the electrical conductivity.

H. D. Seghezzi[12] investigated the tantalum-rich section of the system Ta-N and established the existence of a tetragonal, distorted, metallic phase

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with ordered nitrogen distribution as well as a nitride segregated preponderantly at the grain boundaries.

M. A. Clauss and H. Forestier[12] studied the hydrogen embrittlement of tantalum wires (50 and 100μ thickness) containing minute amounts of oxygen in solid solution. It was found that hydrogen does not affect the elastic characteristics of tantalum. With high rates of loading, fracture occurs in hydrogen at, or in the vicinity of, the yield point.

Production of ductile tantalum was described in detail by G. L. Miller[13]. The preferred technique is powder metallurgy; sintering in a high vacuum conveniently eliminates O, C, N, H, and other impurities simultaneously with densification. Premature densification—that is, closing of the pores before all the gases have a chance to escape—may result in swelling and bursting of compacts, and must be avoided. In arc melting, purification may be achieved by addition of carbon or rare earth elements, but this procedure is considered uneconomical in commercial production.

Osmium

If refractory metals are to be discussed in the order of their decreasing melting points, osmium is the next metal on the list. Its melting point has been redetermined by J. D. Baird, G. A. Geach, and A. G. Knapton[1] as 3000°C ± 200°C. The Vickers hardness of osmium, based on at least 99.7 pct purity, was found to vary from 300 to 670 Dph, depending on the orientation of the surface, the hardness decreasing with increasing angle between surface and the basal plane. The hot hardness of 300 Dph at 1200°C is outstanding (the corresponding values at 800°C are 200 Dph for rhenium and Nimonic 90, and 80 Dph for tungsten).

Although the work-hardening rate of osmium is lower than that of rhenium and columbium, the initial hardness is so high that osmium is unworkable. Osmium oxidizes readily, forming, like molybdenum, a volatile oxide (OsO_4). A systematic study of the system Mo-Os reveals that up to 10 pct osmium reduces the ductility of molybdenum, whereas 14 pct increases ductility so much that 12 pct reduction at 500°C is possible before cracking starts.

Molybdenum

The arc-casting process of the American Metal Climax Co., and the properties and applications of arc-cast molybdenum and its alloys, were discussed by R. Freeman[14]. The major part of a paper of practical interest prepared by N. E. Promisel[7] and Harwood was also devoted to the present and potential future applications of sintered, as well as arc-cast, molybdenum. As far as coated molybdenum is concerned, the prevailing optimism, to a large extent, is based on the recognition that a number of different coatings have proved to possess better self-healing and self-sealing characteristics than previously could be expected. In this respect, the American experience is fully confirmed by the results of the systematic investigations by Bückle[15].

In nuclear engineering, molybdenum, according to E. D. Lloyd[16], can be used in contact with liquid Bi-U alloys. That molybdenum is not corroded by liquid bismuth had been known. The tests reported by Lloyd also indicate the compatibility of molybdenum with Bi-U alloys in the temperature range from 700° to 1000°C. Other experiments reported by Lloyd show the compatibility of tantalum and columbium with liquid bismuth, but permit no conclusions as to performance in the presence of the active metal uranium.

The previously mentioned investigation by Jaffee, Sims, and Harwood confirms the development of remarkable hot plasticity and low-temperature ductility by the addition of 50 wt pct (35 atomic pct) of rhenium to molybdenum. The ductile-to-brittle transition is below 300°F, and the arc-cast alloy can be rolled or forged directly without prior extrusion. The Mo-Re alloy will, in the as-cast condition, permit direct hot working with oxygen contents of at least 500 ppm oxygen, at least 10 times more than can be tolerated by unalloyed molybdenum.

Columbium

Brauer and Müller established the existence of two compounds: an unstable suboxide, Cb_2O, which forms when fine columbium powder is exposed to air at 300°C, and a new hydride, CbH_2, which has the fluorite structure, and is formed by reaction of columbium powder with hydrofluoric acid.

Production, processing, and properties of columbium were reviewed by L. R. Williams and T. J. Heal[17], special attention being given to nuclear applications. As in the case of tantalum, the high-vacuum sintering method is preferred to arc casting, since it combines consolidation with purification. The outstanding properties of columbium refined by electron bombardment were pointed out by C. D'A. Hunt[18], F. Krall[19], D. A. Robins, I. Jenkins[20] and other

Metallwerk Plansee in Reutte/Tyrol, Austria. Administration building at right, and new research institute in background.

speakers. According to Hunt, the production of columbium by electron bombardment has already reached a volume of 2 tons per month.

Silicides

E. Fitzer[m] reviewed heating elements for temperatures above 1300°C with special attention to $MoSi_2$ elements. These silicide elements, which were first shown in operation during the first Plansee Seminar, are protected by the formation of a glassy SiO_2 film. At high temperatures, this film provides protection up to the melting point of the SiO_2 glass, that is, 1700°C. However, when the silicide is exposed at lower temperatures where the molybdenum oxide is less volatile, a Mo-Si double oxide can be formed and lead to destruction of the element. To prevent this type of failure, duplex structures have been developed in which only the parts exposed to the highest temperatures consist of the molybdenum silicide, whereas the ends of the element consist of compounds such as titanium silicide. Such duplex elements have proved successful up to maximum operating temperatures of 1650°C.

The system Re-Si was investigated by A. G. Knapton[l]. Three compounds—$ReSi_2$, ReSi, and Re_5Si_3—were established, all melting below 2000°C, and none oxidation resistant.

Other papers

The contributions by Hunt and Krall and by Jenkins were already mentioned. The first of these papers gave a clear picture of the advantages of electron bombardment heating, of the difficulties encountered, and of the spectacular progress made in this field. Early shortcomings, such as discharges through liberated gases, or contamination of the cathode by these gases, could be prevented by special arrangement of the tungsten cathodes. Of special advantage is the use of two cathodes, one heating the charge to be melted, the other heating the molten pool, thus continuing the degassing process in the molten state. Jenkins described a number of different methods suitable for the preparation of small quantities of high-purity refractory metals. Good results were obtained by applying electron bombardment to zone refining.

M. Auwärter[m] treated in detail the applications of high-melting metals in vacuum technology. B. Natter[n] summarized the applications in furnace constructions. The length of the discussion period was indicative of the interest in the paper of K. Sedlatschek and R. Kieffer[o] on U-W, U-Ta, U-Cb, and U-Mo materials prepared by infiltration of a matrix of the refractory metal with liquid uranium.

W. M. Schwarzkopf and N. J. Grant[m] discussed the properties of dispersion-hardened Ni-Al materials, prepared either by blending the constituent powders or by internal oxidation. H. H. Hausner's paper on slip casting provoked a more general discussion on the possible disadvantages of the application of pressure in techniques of powder metallurgy.

Of special interest was the presentation, by R. Mitsche[m] and H. Blaha[m] of stereoscopic pictures of electron-micrographs, which distinctly showed the spatial distribution of Al_2O_3 inclusions in an Al-Fe matrix. Mitsche proposed the terms *Infra-Cermets* and *Ultra-Cermets* to distinguish between cermet materials preponderant in the metallic and the ceramic phase, respectively.

Second UN Conference on Peaceful Uses of Atomic Energy

by Henry H. Hausner

At the Atoms-for-Peace Conference in Geneva, more than 7000 participants of 68 nations discussed nuclear reactor problems within a period of two weeks. Nuclear physics and health physics were discussed, as well as the problems of nuclear standardization, radio-isotopes, reactor technology, and reactor materials and components. It was very pleasing to me to find that so many papers—in part or in full—dealt with powder metallurgy techniques, as applied to nuclear engineering.

Only seven or eight years ago, metallurgical and materials engineers did not dare to dream how important powder metallurgy would be in the fabrication of materials and components for nuclear power reactors. Many of today's reactor fuel elements are made from metallic or ceramic powders, and cermets play a more important role in nuclear engineering than probably in any other branch of engineering. The powder metallurgy of U, Th, Zi, or Be has been well studied during the last few years, and powder metallurgy production of these materials is progressing in many countries where reactor engineering is in an advanced state.

Nuclear fuel elements

Most of the recent powder metallurgy development work for the fabrication of reactor components concerns the heart of the reactor, the nuclear fuel element. We distinguish three types of solid nuclear fuel: metallic, ceramic, and cermet-type elements.

H. Lloyd and J. Williams[17], investigated the powder metallurgy production of uranium for fuel rods. Attention was concentrated almost exclusively on the consolidation of powder produced by calcium reduction of uranium dioxide. This type of uranium powder seems to be considerably more stable in air than when formed by the hydriding of massive uranium. The Harwell engineers claim that the handling of their powder in dry boxes containing inert atmosphere was, therefore, not necessary for their investigations. This calcium-reduced uranium powder was of spheroidal shape, and 90 percent of the material was smaller than 60μ. The powder can be pressed and subsequently sintered or hot-pressed

HENRY H. HAUSNER is a consulting engineer and adjunct professor, Polytechnic Inst. of Brooklyn. His paper was presented as an informal luncheon talk.

The European Headquarters for the United Nations—the Palais des Nations in Geneva, Switzerland.

below the alpha-to-beta phase transformation temperature. Extrusion of these powders is also possible; however, this can be done only in the gamma phase, above 765°C, where the plasticity of the metal is high enough for the process.

S. K. Kantan, R. V. Raghaven, and G. S. Tendolkar[26], investigated the powder metallurgy of thorium, which increases in importance as a secondary fuel for nuclear reactors. Previous studies have already indicated that fabrication of thorium metal by cold compacting and sintering is possible. Compacting of the powder was done at pressures ranging from 10 to 50 tsi, and sintering was carried out at 1200°C for 1 hr in vacuum. The Indian investigations have shown that calcium-reduced thorium powder can be compacted to a green density as high as 10.75 per cu cm, and maximum sintered density as high as 11.26 g per cu cm. Needless to say, the careful election of particle size is very important in obtaining these results.

Uranium alloys

Uranium alloy powders were developed by direct reduction of the respective oxides, as reported by R. H. Myers and R. G. Robins[27]. The process concerns the co-reduction of mixtures of uranium dioxide and alloy element oxide with calcium in a sealed reaction vessel. Powder is produced with a wide variation in particle-to-particle composition, although with consistent composition for various size fractions. Reduction of compound oxide with calcium does not seem to be very suitable. The particular alloy systems investigated were U plus Ni, Cr, Mo, and Cb. U-Mo and U-Cb powders, especially, seem to be useful for the production of dimensionally stable fuel elements.

An interesting method was disclosed by R. Kieffer and K. Sedlatschek,[6] who prepared uranium alloys by infiltration of porous, sintered, uranium skeletons with low-melting metals. Although this development work was done on a rather small scale, the results are most interesting and very promising.

Uranium compounds

There is a general trend in reactor fuel technology to use uranium compounds instead of metallic materials. It seems that the oxides and carbides of uranium, in particular, have many advantages over the metallic uranium. The main characteristics of ceramic fuel material are high melting temperature, no destructive phase changes, practically no radiation effects, and high corrosion resistance. It appears that the two main disadvantages of ceramic fuel and ceramic materials in general, namely, lower heat conductivity and low-temperature shock resistance, are rather unimportant, as compared with the advantage of operation at considerably higher temperatures. High temperature nuclear reactors are desirable because of their greater efficiency and greater economy.

At the present time, many reactors are equipped with uranium dioxide fuel elements prepared from UO_2 powders by compacting and sintering. Uranium dioxide is an especially interesting oxide, inasmuch as it oxidizes in air—even at room temperature—to a compound of the composition UO_{2+x}, which may even go as high as $UO_{2.2}$ or $UO_{2.3}$. During sintering of these oxygen-rich oxides, the UO_{2+x} decomposes to the stoichiometric compound, UO_2. During decomposition of the oxygen-rich compound, the atoms in the crystal lattice are in a state of high activity and, therefore, cause a kind of accelerated, activated sintering.

The physical properties of uranium dioxide were studied by many investigators in various countries. J. Belle's[28] presentation at Geneva represents probably one of the most carefully made studies of this type. The literature on uranium dioxide has grown very fast, and a recent review which was made in my office showed that more than 300 papers on this subject have been published during the last few years. A large amount of experimental and development work which was disclosed at the Geneva Conference, came from Canada and Sweden. The work of Runnalls[29] may be termed almost as *classic*.

The presentations by Kiessling, Mogard, and Runfors[30] and of Nils Schoenberg[31], indicate that the compacting parameters and sintering conditions for uranium oxide powders depend mostly on the history of the powder. By proper selection of the powder, the use of lubricant, and modification of the sintering atmosphere during sintering, uranium dioxide can be obtained with a density of up to 99 percent of the theoretical. However, it usually is fabricated to a density of only 95 to 96 percent, because a certain porosity seems to be rather ad-

vantageous in order to create space for the fission gases produced in the material during reactor operation.

In developing uranium compounds, one has to consider not only the melting temperature, but also the uranium content per unit volume. From this standpoint, uranium monocarbide offers some advantages, inasmuch as it contains many more uranium atoms than does uranium dioxide. Many attempts in this and foreign countries are, therefore, concentrated on the development of uranium carbide fuel elements. A. Boettcher[19] presented a paper in which he described fuel elements to be used in the gas-cooled German reactor, consisting of compacted uranium monocarbide inserted in a graphite sphere. Charging and discharging the reactor with this spherical fuel is advantageous in many respects.

High density fuels made either from uranium monocarbide or a UC-U cermet have been prepared at the Saclay Research Laboratories of the French Atomic Energy Commission. The cermet was fabricated by hot-pressing mixtures of uranium powder and graphite in suitable proportions. Compacting was done at a pressure of 25 tsi, at 1000°C, for 3 hr.

A similar type of fuel was developed in the USSR, not by compacting powder mixtures, but by infiltration of uranium within a compacted skeleton of uranium monocarbide. It seems that powder metallurgy in the USSR plays a very important role and is highly developed. At the official exhibition in Geneva, the USSR showed fuel elements consisting of U-Mo alloy powder particles dispersed in a matrix of magnesium powder and densified by compacting and sintering. This kind of fuel is used for the first Russian reactor, now in operation for more than three years. I was impressed to learn that more theoretical work in powder metallurgy has been done in the USSR than in many other countries.

Dispersion-type elements

The most common cermet mixtures applied in reactor technology use uranium dioxide particles as dispersants in a matrix of either aluminum, zirconium, or stainless steel. Pioneering work in this type of long-life fuel elements has been done by J. E. Cunningham and R. J. Beaver[20]. The problem of inserting a brittle material in a ductile matrix can be solved only by powder metallurgy. It is important that the dispersed particles are not too fine with respect to the metallic matrix; otherwise they may form a continuous matrix, possibly impairing the mechanical properties of the mixture and having undesirable effects with respect to the distribution of fission gases produced during reactor operation.

P. Murray and J. Williams[17] discussed their work on the insertion of plutonium compound particles in a metallic matrix as a good possibility for the future. Whereas matrix materials for uranium dioxide are limited to a few metals of rather low-neutron absorption cross section, this limitation does not necessarily apply to plutonium-compound-containing cermet fuels. Therefore, matrix materials such as Mo, V, Cb, Ni, or even Ti, or Ta may be taken into consideration. C. J. Turner and L. R. Williams[17], have studied the powder metallurgy of some of these matrix materials, particularly that of Cb and Ta.

R. Kiyoura and T. Sata[22] have investigated another kind of dispersion-type element, made by dispersing uranium-silicide in molybdenum disilicide. The uranium silicides were made by sintering a mixture of uranium and silicon powders. Both materials—the USi and the $MoSi_2$—were then mixed in powder form, compacted and sintered at 1450°C, or hot compacted at 1300°C. Interesting types of fuel were also obtained by the solid solution of uranium dioxide and thorium dioxide in powder form, to be used as a dispersant. I should like to call to your attention that this solid solution of the two oxides was originally developed at Argonne National Laboratory, and has proved to be an excellent fuel. The insertion of this solid solution into various matrices offers many possibilities. Beryllium oxide has been considered by the Japanese engineers to be a good matrix material, because a fuel element of this type combines fuel and moderator in one single unit.

One of the most interesting fuel elements was exhibited by the British in Geneva: a tubular element consisting of uranium fuel clad with beryllium. This beryllium, made at Aldermaston, England, and described by T. R. Barrett, G. C. Ellis and R. A. Knight[1] is, at least as far as I know, the first beryllium which is ductile in all three directions of the crystallographic axis. It is also a powder metallurgy product; not made, however, by pressing the powders, but by sintering loose beryllium particles close to the melting temperature of the material—a technique which also permits fabrication of tubes for fuel cladding purposes. The material has outstanding physical properties.

Summary

I definitely have not given a complete review of the Geneva discussions on powder metallurgy in nuclear engineering, but it will indicate the importance and growth of powder metallurgy in this latest field of engineering. There is a general trend to apply powder metallurgy more and more for the production of nuclear materials and components, and we believe strongly that powder metallurgy will continue and will grow in this field.

The only difficulty that I can see is the safe handling of these powders, some of which may be toxic, or pyrophoric, or dangerous on account of radiation. However, we have learned today to operate with these sometimes dangerous powders, and have developed the proper equipment to guarantee practically safe handling of these materials.

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WHAT'S HAPPENING TO TITANIUM ALLOYS?

What are the new titanium alloys that are increasing the role of this metal in the missile age? Recent developments that are responsible for a renewed emphasis on titanium were discussed at the Titanium Symposium of the 1958 Fall Meeting of The Metallurgical Society.

A Summary of the Panel on New Alloys,

Titanium Symposium of the 1958 Fall Meeting

Of particular interest to titanium-minded metallurgists attending the 1958 Fall Meeting in Cleveland, was a panel discussion on new alloys—a part of the annual Titanium Symposium. Robert I. Jaffee, chief of the nonferrous physical metallurgy div., Battelle Memorial Institute, acted as moderator. Members of the panel were:

Lee S. Busch, director of research, Mallory-Sharon Titanium Corp.;

Walter L. Finlay, director of research, steel, titanium, and special alloys, Crucible Steel Co. of America;

Schuyler A. Herres, technical director, Titanium Metals Corp. of America;

Harold Margolin, associate professor of metallurgical engineering, New York University;

Thomas E. Perry, titanium metallurgist, Central Alloys District, Republic Steel Corp.

Background Information

Dr. Jaffee: One of the first targets set by the aircraft industry for titanium alloys was a sheet alloy with 150,000 psi yield strength and 10 pct elongation. In 1948 this target appeared distant indeed, and the first samples offered were annealed alpha-beta alloys of the 110,000 psi yield strength class, which were the easiest to produce. They included Ti-8Mn, Ti-1.8Fe-3Cr, Ti-4Al-4Mn, and Ti-2Fe-2Cr-2Mo.

These alloys had been used for aircraft sheet and forgings for several years when the problem of hydrogen embrittlement arose in non-aluminum-containing alpha-beta alloys. The Ti-6Al-4V alpha-beta alloy was under development for ordnance applications. This and the Ti-4Al-4Mn answered the hydrogen problem for jet engine forgings. Since that time, the Ti-6Al-4V alloy has been one of the mainstays of the titanium industry.

Although airframes were made with riveted construction, there was a need for a weldable alloy in jet engine casings and shrouds. An alpha titanium alloy was the logical answer to this problem because it would not undergo transformation hardening, and would produce a ductile joint in the as-welded condition.

A shortcoming of the Ti-Al alloys was that if the alumium content was much higher than 5 pct, workability was diminished. One early solution to this problem was the Ti-5Al-2.5Sn alloy; the aluminum content was limited to 5 pct and the auxiliary, alpha-soluble tin increased strength with equivalent ductility and fabricability.

New target strengths for sheet: Annealed formable sheet of the 110,000 psi class alloys, for riveted construction in aircraft, was being threatened by precipitation-hardened steels of 190,000 psi strength. The titanium industry needed a sheet alloy which could be formed in the solution-treated condition and aged at high strength for application in riveted construction of airframes. Targets of 160,000 psi yield strength, 180,000 psi ultimate strength, and 10 pct elongation were set. You will note that the target strengths were creeping upwards. The result was the selection of the US Dept. of Defense Sheet Rolling Program alloys which now are in the phase III evaluation.

A number of problems arose with the production of the Sheet Rolling Program alloys in connection with the manufacturing of large, flat solution-treated sheets. In order to attain the solution-treated condition, it was necessary to cool the sheets rapidly. Accomplishing this with 36x96 sheets from temperatures of 1400° to 1700°F was no mean task. Remarkable progress has been made toward the solution of this problem; however, it still remains a difficult task.

Perhaps a better solution to the problem is an alloy which is so sluggish in its reaction kinetics, that it may be air- or furnace-cooled from the solution temperature. This, of course, greatly simplifies the problem of heat treatment. One such alloy is Ti-13V-11Cr-3Al, the B120VCA alloy. However, associated with the advantage in slow reaction kinetics for solution treatment, is a corresponding disadvantage in long-aging cycles needed to develop good strength.

The jet engine industry, meanwhile, was busy designing Mach 3 engines, which run much hotter than the Mach 1 to 2 enignes, for which the Ti-6Al-4V was suitable. Alloys which would be satisfactory for airframes in Mach 3 aircraft would be unsatisfactory for engines. The latter run about 400°F hotter than the foresection and about 200°F hotter than the aft section, which is heated by the engine as well as aerodynamically.

Pratt and Whitney Aircraft Co. set some really tough targets (tough at the time they were set, at any rate). They required that the alloy undergo less than 0.2 pct plastic deformation in 150 hr, at 800°F and 65,000 psi, and at 1000°F and 25,000 psi. The problem was particularly difficult, not only from the viewpoint of developing alloys which would attain sufficient creep strength under these arduous conditions, but because at about this time a new problem reared its head—that of instability in highly alloyed alpha bases, such as Ti-Al with aluminum contents of 7 pct or more. Since highly alloyed alpha bases offer practically the only solution to the problem, you see that the alloy developers here were in a nice little box.

Everything was progressing nicely for the titanium industry, and many of the existing and new alloys had good prospects, indeed, when suddenly a new situation arose—**the missile age.** This was an acute situation for the industry, because accompanying the advent of missiles were cancellations and stretch-outs of manned aircraft production, the backbone of the titanium market. There were two parts to the missile problem: one technical, the other educational. On the educational side, whereas the missile men were used to steel and magnesium, they had to be educated with respect to titanium capabilities. For the titanium people, education was necessary with respect to problems that might be encountered with titanium alloys.

At the present time, titanium seems to fit into the missile picture in a number of ways. If the prospects for some of the new alloys bear out, considerably increased markets should result. The missile applicaton demanded weldable alloys in many places including pressure bottles, solid fuel containers, and fuselage sections. The pressure bottles had to be both strong and ductile at liquidified gas temperatures, down to −320°F for liquid oxygen and to −420°F for liquid hydrogen.

The old standby, Ti-6Al-4V, made the first dent in the pressure bottle application. Some of the new alpha-type alloys with better low-temperature toughness should come to the front for more difficult applications. The solid fuel cans required even greater strength; well over 200,000 psi was required in order to compete with steels. The beta VCA alloy has made a significant impact on the solid fuel can problem. Strengths approaching 250,000 psi have been developed in this alloy in forms intended for this application.

Large missiles and heavy bombers have provided new problems and opportunities for titanium alloys. **Sandwich construction** is one of the chief methods of construction used on such vehicles. At present, stainless steel is the principal sandwich production material. Titanium alloys capable of being rolled to foil gages for the core, and rolled to thin-gage, large-sheet sections for cover sheets. are required. The heat-treatment kinetics of such alloys should be such that they are capable of being either welded or brazed into honeycomb panel sections and still develop high strength on subsequent aging. Some of the older alloys, such as RS-140, and some of the newer alloys, such as VCA, look promising for this application.

Titanium Metals Corp.

Dr. Herres: To the relief of those of us who listen to panel discussions, midnight has long past for titanium as the Cinderella metal. But whether you want titanium plain or fancy, it is still a problem when related to future products. In the expensive forms for aircraft and missile requirements, titanium alloy potentialities are as dazzling as ever. The capabilities of known alloy systems are strained to the utmost, and the cost is high.

In plainer form, and in volume production for the multitude of applications involving desirable strength:weight ratios, good corrosion resistance, formable and weldable titanium will compete in cost with other base materials for a broad market.

Titanium Metals' research and development program budgeted at well over one million dollars annually—exclusive of plant process improvements and control—is divided into five parts. Four divisions—located at Henderson, Nev.—include Process Research (ore through sponge), Melting Research, Development Engineering, and Basic Metallurgy Research.

The fifth division is located at TMCA's plant in Toronto, Ohio. The function of this Product Development division is to develop mill processing procedures for new alloys and new products.

Approximately one half of our effort is devoted to producing better and cheaper metal and ingots; the other half reaches toward developing new and improved alloys and products, which tend to be more expensive to make.

Among the new alloys in the development stage, those which appear most important to me at the moment are **heat-treated, high-strength sheet.** The Ti-4Al-3Mo-1V alloy was covered in earlier discussions.

The Ti-6Al-4V alloy, which we accepted in the US Dept. of Defense contract as a commercial product, cannot be regarded as a new alloy. However, its divergent new uses are far different from those for which it was originally designed. The 6-4 alloy has a practical combination of weldability, heat-treating ability up to 160,000 psi (depending on section size), and formability that makes it attractive for propellent containers, heat-treated forgings, and cryogenic bottles (to a min of−320°F) These properties, combined with extensive production experience, create difficult competition for less extensively developed new alloys.

For heat-treated bar, forging, and fastener applications, the Ti-4Al-4Mo-4V alloy is in the customer evaluation stage. In fastener stock its strength is approximately 200,000 psi tensile and over 110,000 psi shear. It has been roll-threaded commercially in this condition. The alloy is remarkable for its notch resistance (240,000 psi for tensile unnotched strength of 200,000 psi).

For elevated temperature applications, the 8Al-1Mo-1V alloy has been found to have usable strength at 800° to 1000°F without instability. At 150 hr, 800°F and 65,000 psi or 1000°F and 25,000 psi, creep deformations are approximately 0.2 pct. Billet, bar, and sheet products are being produced in develop-

ment quantities. Welding test results indicate better weld-bend ductility than found in Ti-6Al-4V.

Other applications: Ti-6Al-4Zr-1V alloy is being developed for applications requiring good room-temperature strength with optimum welding and forming characteristics. This Al-Zr addition approaches the maximum for elevated temperature strength combined with stability and reasonable formability.

A major effort is being devoted to commercialization of strip-rolling techniques for Ti-6Al-4V, Ti-4Al-3Mo-1V, and other alloys in widths up to 48 in., and in gages down to 0.010 in.

The all-beta alloy, long discarded because of elevated temperature instability, is receiving new life for missile applications. In the aged condition, its strength:weight properties are the most attractive that we have seen. Experience is still limited as to practical applications.

Crucible Steel Co.

Dr. Finlay: Crucible believes that the best in titanium is yet to come. Cost is decreasing and quality is improving. New alloys are coming in and new combinations of properties are being realized.

For example, Crucible has been working for some years with what we refer to as a super alpha titanium alloy—an alpha Ti-Al base with something added to give it higher strength. Almost two years ago we tentatively announced a new super alpha titanium alloy, Rem-Crucible 900, containing 4Al-12Zr. This was the first Ti-Al-Zr-base alloy, and we believe this family will provide the lightest strength:weight alloys for service in the 800° to 1200°F region.

For missile applications and for long service up to 600°F, the first beta titanium alloy, Crucible B120VCA, offers the highest strength:weight ratio of any structural sheet. It is the most versatile titanium base alloy yet developed. It has both the highest strength and the best formability of any titanium base material.

B120VCA is ductile-weldable, cold-heatable, and has very great and deep hardenability which appears to fit it for high strength:weight honeycomb foil at one extreme, and for very thick heat-treated sections at the other extreme. These outstanding properties result from the highly alloyed, beta titanium structure that contains 13½V-11Cr-3Al.

New York University

Dr. Margolin: Our alloy work at NYU has been concerned with two rather different areas based on the requirements of the sponsoring agency. **For Watertown Arsenal,** our objective has been to develop alloys with desirable yield strengths and impact energies.

Initially, the requirements were to develop transverse 0.1 pct yield strengths of 150,000 psi or better, with charpy impact energy absorption of 10 ft/lb or better at −40°F and appropriate tensile ductility. The 0.1 pct yield strength requirement was subsequently raised to a 0.1 pct yield strength of 170,000 psi. At present there is interest in 0.1 pct yield strength of about 200,000 psi. The section sizes used for tests are 5/8 in. plate, 5 in. diam.

Our point of departure for alloy improvement was the Ti-6Al-4V composition. We have found Sn, Fe, Cu, Mo, and Zr of value in achieving higher strengths. As one would expect, the amounts of the various alloying agents that produce desirable properties are not the same, and aside from aluminum, the largest alloying addition which can be made is zirconium.

For ½ in. sq rod, the optimum properties achieved are a 0.1 pct yield strength of 185,000 to 190,000 psi, tensile strength of 190,000 to 200,000 psi, reduction of area of about 34 pct, and impact energies in the range of 10.8 to 12 pct. (Best properties achieved are 196,000 psi, 0.1 pct yield strength, 212,000 psi tensile strength, 7.5 pct elongation, 24 pct reduction area, and 8.8 ft/lb.)

In transverse properties and section sizes of 1 to 1.5 in., Watertown Arsenal has achieved strengths of 10,000 psi lower, at about the same or somewhat lower ductilities. These properties are, perhaps, not unusual today, but the results indicate that 0.1 pct yield strengths of 200,000 psi with adequate ductilities are attainable.

For the Wright Field Materials Laboratory, our problem was concerned first with the demonstration as to whether or not α + compound active eutectoid alloys possessed desirable properties and, if so, how to improve them. We have obtained data which indicated that α + compound alloys do possess good potential for elevated temperature applications. The alloys explored are basically Ti-Cu-Al alloys to which Sn and Zr have been added. In general, Al is the most effective strengthener, followed by Cu, Zr, and Sn. Similar properties can be obtained in a number of instances by appropriate variations in compositions.

The strongest alloy which we have tested so far is the Ti-6Cu-7Al-6Zr which, at room temperature, has a tensile strength of 165,000 psi, 9.8 pct elongation, and 15 pct reduction area. At 1200°F the alloy has a short-time tensile strengtn of 109,000 psi and is quite ductile. At 1000°F and 60,000 psi, the alloy shows a rupture life of 345 hr, and at 50,000 psi the rupture life is 695 hr. The principle problem with this alloy and similar alloys is stability, although for some missile applications this may not be a problem.

Our approach toward reduction of instability is twofold—to back off some in composition, and to try heat treatments which we believe might be conducive to increased stability.

Insofar as future trends are concerned, I think that on the basis of present knowledge, the use of aluminum to raise elevated temperature probably will be under 15 pct Al and may be extended above 8 pct. Probably we will see more attempts at working in the beta field, and as we learn more about the interrelation of mechanical working and heat treatment, we will extend the ranges of heat-treated properties of beta-containing alloys above 220,000 to 250,000 psi.

Republic Steel Corp.

Mr. Perry: About two years ago, Republic Steel Corp. began to develop a high strength, heat-treatable titanium alloy sheet with properties generally consistent with the aims of the US Dept. of Defense Sheet Rolling Program. The program had a two-fold purpose: that of developing a suitable alloy system, and the development of suitable full-scale process equipment to permit the production of such alloy in flat, solution-treated, or solution-treated and aged conditions.

The alloy selected was designated RS-140. It contains 5 pct Al, 2.75 pct Cr, and 1.25 Fe. A low interstitial alloy, R-140 has the advantage of low solution-treating temperatures (between 1400° and 1500°F). Solution treating in this range, followed by aging for 6 hr at 900°F, results in tensile strengths of between 180,000 and 200,000 psi, with good remaining ductility.

The density of RS-140 is approximately the same as that of commercially pure titanium. It may be formed in the solution-treated condition and subsequently aged to the high tensile strengths required in service. There are good indications that this alloy may be warm formed in the solution-treated condition at temperatures as high as 1050°F, and subsequently aged at 900°F to attain high strength properties. In the event that the warm-forming technique is used, it is desirable to solution treat the material from somewhat higher temperatures.

Where long times and high stress are involved in end usage of this grade, the upper service temperature is about 700°F, based on stability testing. In gages heavier than approximately 0.090 in., RS-140 has usable fusion weldability.

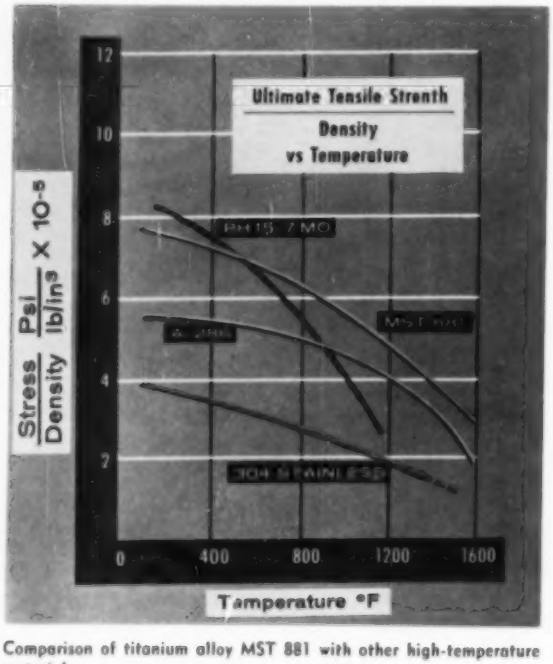
Processing equipment: Maintaining good flatness and solving the problem of solution-treating sheet material was simplified due to the relatively low solution-treating temperatures of RS-140. The mechanical processing equipment ultimately evolved, consists of a continuous electric roller-hearth furnace with five-zone temperature control that solution treats the sheets continuously and delivers them to a roller quenching type of apparatus. Numerous destructive tests of full size sheets show that this equipment can deliver solution-treated sheet that is uniform in heat treatment response and that has good flatness.

The aging apparatus, which will accommodate sheet up to 48 in. wide and 120 in. long, consists of electrically-heated cast-iron platens which permit very close temperature control over the entire surface of the sheet during the aging process. We have found that during aging, the heavy (6 ton) platens actually improve the flatness of the solution-treated sheet significantly.

The basic processing equipment has been evaluated successfully using other heat-treatable alloys such as the 4Al-3Mo-1V alloy, the 16V-2.5Al alloy, and the 6Al-4V alloy.

Other alloys: We have been examining the mechanical properties combinations which can be developed on continuously cold-rolled titanium alloy strip of the 6Al-4V analysis, as well as the RS-140, 5Al-2.75Cr-1.25Fe analysis. These grades can be produced on cold strip mills with or without significant directionality, depending on the processing. While minimum directionality is desired for many applications, it is also possible to develop high yield and tensile values in one direction for special applications where high strength in one direction of loading is required.

We are extremely interested in the all-beta type titanium alloys, and we have evaluation programs under way. We also have several active programs in which high aluminum alloys in the range of 7 to 10 pct are being investigated, together with smaller additions of beta stabilizers for applications where higher hot strength is required.



Comparison of titanium alloy MST 881 with other high-temperature materials.

Mallory-Sharon

Mr. Busch: As indicated by the previous speakers, it is evident that titanium alloys are available today ranging from 30,000 to 200,000 psi yield strength. This range of strengths is available in approximately 20,000 psi increments.

My colleagues discussed, in general, materials that have high strengths at room temperature. Another field, that of high-temperature alloys, has utilized large quantities of titanium in the past, and indications show capabilities of greater development.

In the past, titanium has been limited to use in thermal environments up to about 750°F. Today titanium alloys are being used at temperatures up to about 850°F. A recent article published in the JOURNAL OF METALS, indicates the ultimate capability of titanium to be in the range of 1600°F.[1]

A new alloy recently developed by Mallory-Sharon's research laboratory, containing 8 pct Al, 8 pct Zr, and 1 pct Ta plus Co—the balance being titanium—has indicated a capability for long-time use at 1100°F and excellent short-time properties at temperatures up to 1600°F. The MST 881 alloy is presently available in bar and billet form, but sheet is considered to be experimental. It is interesting to note (Fig. 1) that MST 881 has as good strength at 1600°F as A286, and when compared with the latter on a strength:density basis, is about 25 pct superior at 1600°F.

In summary, then, a new titanium base alloy has been introduced which shows great promise in extending the use of titanium at high temperatures, and is competitive with those materials commonly thought of in design considerations for supersonic aircraft and engines.

[1] C. M. Brown and R. W. Fountain: New Metals Face the Future, JOURNAL OF METALS, vol. 10, May 1958, pp. 330 to 334.

DEFINING URANIUM CONCENTRATE SPECIFICATIONS

Effective growth of the uranium industry made it imperative that uranium-concentrate specifications be defined and continuously reviewed. This the AEC has accomplished through its Joint Committee on Uranium Concentrate Specifications and successor committees.

by J. R. Nelli, W. C. Manser, and D. S. Arnold

As recently as six years ago, specifications for uranium concentrate were established on the basis of individual negotiation with producers. But as the supply and demand for uranium concentrate increased, the US Atomic Energy Commission recognized the problems associated with individually negotiated specifications. Consequently, the Joint Committee on Uranium Concentrate Specifications was established in 1953. Its function was: 1) to study the relationship between uranium concentrate specifications, uranium recovery, and overall cost to the AEC and, 2) to recommend specifications for uranium concentrate procurement.

In the summer of 1955, the Committee formally recommended a set of specifications which were subsequently used as a basis for procurement contracts (see Box).

The Committee also compiled basic information for use by the AEC in pricing sub-grade concentrates (through price reduction schedules) in order to facilitate procurement of uranium concentrates in time of scarcity. This information provided a reasonable basis for purchasing concentrates which, although not up to specification standards, could be used to augment supplies of specification grade concentrates.

In the preface of its report, the Committee observed that the revision of specifications would have to take into account improvements in milling and refining technology, changes in the character of ore deposits, and changes in the end use requirements of the purified uranium.

Nuclear reactor design and operating requirements dictate the specifications for the uranium product supplied by the refinery. Elements affecting product purity are those which have high neutron cross-sections, and those which affect the metallurgical properties of the uranium metal. An analysis of uranium metal product purity, showing impurity concentrations and thermal neutron cross-sections of these concentrations, is shown in Table I.

J. R. NELLI, W. C. MANSER, and D. S. ARNOLD are with the National Lead Co. of Ohio at Fernald, Ohio. This paper was presented at the 1958 AIME Annual Meeting.

Uranium Concentrate Specifications*

The desired specifications determined on a dry weight basis for uranium concentrate are:

1. Min U_3O_8 content of 75.00 pct.
2. Max V_2O_5 content of 2.00 pct of the U_3O_8 content.
3. Max PO_4 content shall not exceed the sum of 1.31 times the iron (Fe) content plus 2.00 pct of the U_3O_8 content provided that the total phosphate content shall not exceed 6.00 pct of the U_3O_8 content.
4. Max Mo content of 0.60 pct of the U_3O_8 content.
5. Max B content of 0.030 pct of the U_3O_8 content.
6. Max halogens, Cl, Br, and I, expressed as Cl, content of 0.10 pct of the U_3O_8 content.
7. Max F content of 0.10 pct of the U_3O_8 content.
8. Max Cu content of 1.70 pct of the U_3O_8 content.
9. Max As content of 0.80 pct of the U_3O_8 content.
10. Max CO_3 content of 1.00 pct of the U_3O_8 content.
11. Max SO_4 content of 15.00 pct of the U_3O_8 content, provided that multiplying 100 times the ratio of Ca content to U_3O_8 content by 100 times the ratio of SO_4 content to U_3O_8 content will give a product that does not exceed the number 8.50.
12. Max moisture H_2O content of 10.0 pct (determined on an *as received* basis and drying at 110°C).
13. All uranium concentrate shall pass through a ¼ in. screen.

* The following changes have been made to the above table:

5. Max B content = 0.20 pct.
8. Deleted.
9. Max As content = 2.0 pct.
10. Max CO_3 content = 4.0 pct.
11. Max SO_4 content (including total sulfur reported as SO_4) revised to 10 pct of the U_3O_8 content.
13. All uranium concentrate shall pass through a screen with a ¼-in. opening.
14. Max Ca content of 1.5 pct of the U_3O_8 content.
15. Max amount of U_3O_8 insoluble in nitric acid to be 0.10 pct of the U_3O_8 content as determined by the standard method used by the AEC for making all such determinations for insolubility of U_3O_8.

Specifications on Th, rare earths, and organic content are still under consideration pending results of current process development and evaluation work. All measurements are listed in dry wt.—ED.

Effects of impurities upon metallurgical structure and mechanical properties of uranium have been discussed by various authors. Foote points out the effect of small amounts of impurities on α uranium by formation of a second phase, due to limited solubility in uranium.[1] The same paper reports examples of the effects of C, N, Si, Fe, and Ta impurities.

Gardner and Riches further describe the effects of hydrides and carbides on uranium physical metallurgy, which manifest themselves in changes in tensile ductility of the metal.[2] Zegler and Chiswik have investigated the effects of Mo, Si, Al, Ti, V, and Cb on the dimensional stability of uranium during thermal cycling.[3]

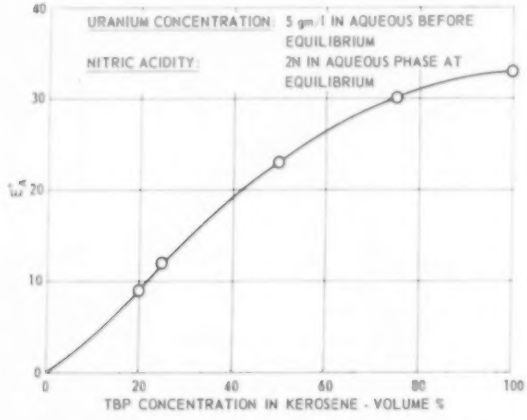
It has been determined that regulation of uranium purity is required to control grain size; this, in turn, provides the necessary ductility and tensile strength for fabrication of the fuel elements, as well as the thermal and irradiation stability needed for suitable reactor performance.

Purification limitations

Impurities, including those mentioned above, are found in the aqueous uranyl nitrate (the final product of the solvent extraction process from which the uranium metal is ultimately produced) as a result of co-extraction with uranium by the organic solvent, and aqueous or solid entrainment in the organic extract. Although the tributyl phosphate is highly selective with respect to uranyl nitrate, it does extract other metal nitrates, as indicated by extraction distribution coefficients in Table II, and by the solubility data of Wendlandt and Bryant.[4]

The distribution coefficient, E^{o}_{A}, is defined as the ratio of the metal concentration (in mol per mol) in the organic phase to that in the aqueous phase at equilibrium. It is a function of the metal, tributyl phosphate (TBP), and HNO_3 concentrations. Although some of the distribution coefficients listed are high, they are all greatly reduced in the presence of uranium, and they attain considerably lower values when the TBP is saturated with respect to uranium.

The data listed in Table II have been collected from numerous sources and represent a variety of conditions which are not directly comparable. The figures shown in the table have been tabulated to indicate an order of magnitude effect of the extraction tendencies of different impurities. Considerable experimental work would be required to quantitatively evaluate the interaction effects of different possible permutations and combinations of impurities and their concentrations. For practical reasons, therefore, the uranium concentrate specifications must be based upon specific current or projected uranium ore and concentrate compositions.



Uranium coefficient as a function of TBP concentration.[15]

Solid entrainment in the organic extract, such as finely divided siliceous or carbonaceous materials, may cause contamination by adsorbing many metal ions which are then re-extracted into the final aqueous product. Aqueous entrainment in the organic extract results when clean separation of the two phases is hindered by the presence of finely divided particles and surfactants.

Physical operation problems

Various aspects of refinery physical operation must be considered as factors in determining yellow cake specifications.

Scale deposition results in the reduction of column efficiency and throughput and in the plugging of valves and lines. Scale formation necessitates costly shutdowns for cleanout. Materials which may contribute to excessive scaling include calcium, lead, sulfate, silica, vanadate, phosphate, barium, and radium. The decrease in calcium sulfate and lead sulfate solubility as the uranyl nitrate concentration is reduced—such as occurs in countercurrent extraction—is shown in reference 5.[5] Data of this type provide a basis for specifications on these materials to avoid extraction system scaling and plugging. Arnold and Ryle have reported further observations on scaling from these materials alone and in conjunction with insoluble silica.[6,7]

Emulsification in the extraction columns causes uranium losses, product contamination, and loss of production capacity. Emulsification may result from introduction of materials which modify the physical properties of the two-phase, aqueous-organic system. Soluble silica, finely divided silica or carbon particles, surface active agents such as flocculants, and other organic compounds will contribute to emulsification and ultimately to disruption of refinery operation. These materials must be controlled by specification of the uranium concentrates or by special feed-preparation processing steps at the refinery.

Corrosion: Recovery of nitric acid from extraction-column raffinates is necessary from the point of view of production costs and public health regulations. Corrosion of fluorides and chlorides in nitric acid, is severe at elevated temperatures, thereby constituting a major problem in nitric acid recovery operations in the refinery. The necessity for maintaining close control on these halides in uranium concentrates has been detailed in previous papers.[8,9]

To avoid expensive installation and operation of filtration equipment for clarification of the extraction feed, the digested feed is pumped as a slurry to the extraction columns and then to the raffinate processing facilities.[7] Although the slurries are pumped through recycle loops to minimize settling, line plugging and pump and valve erosion may result from excessive solids. Problems in slurry handling require control of uranium assay, insoluble solids content, and particle size.

Presence of significant quantities of reducing agents, such as sulfides in the uranium concentrate,

will lead to excessive fuming and foaming through increased generation of nitrogen oxide gases during digestion. The presence of carbonates in the feeds gives the same effect by CO_2 evolution. Carbonates in the feeds limit the refinery digestion capacity, represent operational safety hazards, and increase the nitric acid consumption in the digestion step.

Health and Safety aspects of refinery operation require control of the amount of arsenic, organics, and other materials that generate highly toxic gases or explosive compounds by reaction with acid and/or uranyl nitrate. The presence of radium requires special handling procedures for the protection of operating personnel and for waste disposal.

Uranium recovery efficiency

Uranium recovery in digestion and extraction demands certain specification considerations. Nitric-acid-insoluble uranium may result from concentrate calcination at excessively high temperatures or from the presence of specific nitric-acid-insoluble uranium compounds, such as uranous phosphate and uranium tetrafluoride.

Uranium recovery in the extraction step is reduced by excessive amounts of sulfates, phosphates, vanadates, molybdates and arsenates.[6,10,11,12] The anions in the aqueous phase form uranyl complexes which are not extracted into the organic solvent. At higher concentrates, these complexes precipitate from the aqueous solution, thereby further reducing uranium recovery. The presence of copper aids the formation of some precipitates. It is possible to minimize uranium losses through these conditions by use of higher acidity, salting agents, or sacrificial cations (salting agents). However, in each case a significant economic and production burden on the refineries is involved.

Uranium recovery may be reduced further by the presence of surfactants that are capable of decreasing the rate of mass transfer of uranium.[13] The result may be loss of uranium in the aqueous phase during the extractive step or incomplete stripping of the organic phase in the re-extraction step.

Conclusions

The factors determining uranium concentrate specifications are found in mining, milling, refining, fabricating, and nuclear reactor design, and in operating problems and capabilities. Effective growth of the uranium industry has made it imperative that specifications be defined in such a manner as to achieve the most economical operation of the entire production chain from the mine to the reactor.

Continuous review of the specifications must be maintained in order to provide a sound basis for adjustment when the opportunity presents itself. To achieve this end, the AEC has established a committee as a successor to the Joint Committee on Uranium Concentrate Specifications, assigning to it the task of continually investigating technical and economic factors of uranium procurement.

Major progress has been achieved in all areas of the uranium industry in a few short years, and further progress is to be expected.

Table I. Typical Analysis of Normal Uranium Metal for Use in the US AEC Civilian Application Program

Impurity	Impurity Concentration[a]	Thermal Neutron Cross Section[b]
B	0.25	42.044
Fe	150	0.027
Mn	25	0.145
N	100	0.081
Ni	100	0.047
Mg	25	0.0016
C	150-750	0.00016
Cl	30	0.537
Si	65	0.003
Cr	65	0.034
Ag	1	0.346
Cd	0.20	13.668

[a] Parts by wt impurity per million parts of U.
[b] Sq cm per g of impurity in uranium matrix.

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Table II. Distribution Coefficients of Metal Nitrates

Metal	Metal Conc[a] G per L	TBP,[b] Pct	Temp, °C	HNO_3,[a] N	Dist Coef $E°_A$
U (VI)	10.0	40	—	3.0	7.2
	0.56	50	—	3.0	47.0
Th (IV)	12.6	30	30	3.0	1.7
	10.0	100	—	0.0	0.44
	37.0	50	—	3.0	1.5
Fe (III)	10.0	20	—	2.0	0.014
	1.7	60	—	3.0	0.025
Bi	10.0	20	—	2.0	0.013
La	10.0	100	—	0.0	0.30
	<1.0	48	25	5.2	0.019
Cu	10.0	20	—	2.0	0.0094
Cd	10.0	20	—	2.0	0.0081
Zn	10.0	20	—	2.0	0.0089
Co	10.0	20	—	2.0	0.0084
Pb	10.0	20	—	2.0	0.0051
Rare Earths	11.4	60	—	3.0	0.065
Gd	10.0	100	—	0.0	0.4
	1.33	100	24	13.1	6.9
Dy	10.0	100	—	0.0	0.4
	0.21	100	24	12.5	13.0
Y	10.0	100	—	0.0	0.33
	<1.0	19	25	2.26	0.014
	<1.0	48	25	1.95	0.048
Ce	10.0	100	—	0.0	0.31
	<1.0	48	25	2.7	0.056
Pr	10.0	100	—	0.0	0.31
	<1.0	48	25	2.57	0.116
Eu	<1.0	48	20-23	2.00	0.136
Sm	10.0	100	—	0.0	0.36
	18.5	60	25	12.3	0.55
	3.61	100	24	12.8	2.13
Nd	10.0	100	—	0.0	0.38
	19.7	60	25	12.3	0.17
Zr	37.0	30	—	4.92	0.21
	Tracer	30	Rm	2.0	0.042
	Tracer	30	Rm	4.9	0.301
	22.0	60	Rm	~3.0	0.49
Hf	~300.0	60	Rm	~3.0	0.038
Ti	2.0	50	—	3.0	<0.003

[a] Concentration in the aqueous phase at equilibrium.
[b] Tributyl phosphate.

IS ATOMIC POWER

To an industrial customer or a utility executive considering an atomic power plant today, the natural question is, "What is it going to cost me to buy and operate the plant, and how is this cost picture likely to change during its normal life expectancy?" This article attempts to answer these questions.

Summarized from a paper by W. L. Budge

AT present many concepts of nuclear power plants are under consideration. Some have been built and operated, others are in the process of being built, and some are just rough possibilities. A prime consideration in all of them is the cost at which they are capable of producing electrical power.

In order to review the cost trend of atomic power plants, three main cost factors must be considered: capital costs, operation and maintenance costs, and fuel costs.

Three cost factors

The average capital cost of a present day fossil fuel plant is about $165 per kw of generating capacity. Some large plants have been built for considerably less. Today in comparison, atomic plants are much more expensive. For example, the capital costs estimates for such plants as the Consolidated Edison Station at Indian Point, N. Y. and the Yankee Atomic Electric plant near Rowe, Mass., are in the range of $300 to $400 per kw of generating capacity.

As we know them today, the operation and maintenance cost differences between fossil-fuel and atomic plants are negligible.

Fuel costs vary greatly in atomic plants depending upon the type of plant, the accounting practices used, and the credit or subsidy assumptions made.

Total costs

The total production costs for conventional plants vary according to geographic area throughout the US. The present average total cost of power production in the US is approximately 7.5 mils per kw-hr for conventional power stations.

Using the same accounting method, and employing conservative fuel costs for plants of 150,000 to 200,000 kw generating capability to be placed in operation by 1960/62, the estimated production cost of atomic power is from 11 to 15 mils per kw-hr, or an average of perhaps 13 mils. If we compare the 13-mil figure of atomic power plants with the 7.5-mil figure of fossil fuel plants, we still have a long way to go before atomic power becomes competitive.

Operating and projected plants

Since 1948, a number of atomic plants have been placed in operation. These plants have been largely of the prototype or feasibility demonstration nature. Examples are, the boiling-water plant at Argonne National Laboratory in Chicago, the General Electric boiling-water plant at Vallecitos, Calif., and the North American sodium-cooled plant at San Jacinto, Calif. These plants have proved the feasibility of atomic power and have provided data for design and cost estimates of full-scale plants.

The Shippingport plant, the world's first large-scale atomic plant devoted exclusively to peaceful uses, is another milestone in our progress. The primary purpose of the 60,000-kw Shippingport plant is to advance the technology of pressurized water reactors rather than to generate electricity at costs competitive with ordinary fuels. However, operation of the plant since December 1957 is providing information from which reliable cost estimates can be made.

The Shippingport cost figure of 64 mils per kw-hr as compared with our presently anticipated figure of 11 to 15 mils per kw-hr is indicative of a tremendous advance in a very short period of time. Some factors in this cost change are:

1) As a development plant, there are many features of Shippingport which are not required solely for the production of power; therefore, the capital cost of this first plant was necessarily higher than plants to follow. The expected output of the Yankee Electric plant is more than twice the rated output of the Shippingport plant. The Yankee estimate indicates that total capital costs will be less than those of Shippingport, thereby cutting the capital cost portion in half;

2) Research and development work has indicated that fuel life can be extended for the same fabrication costs; therefore, there will be a proportionate reduction in fuel costs.

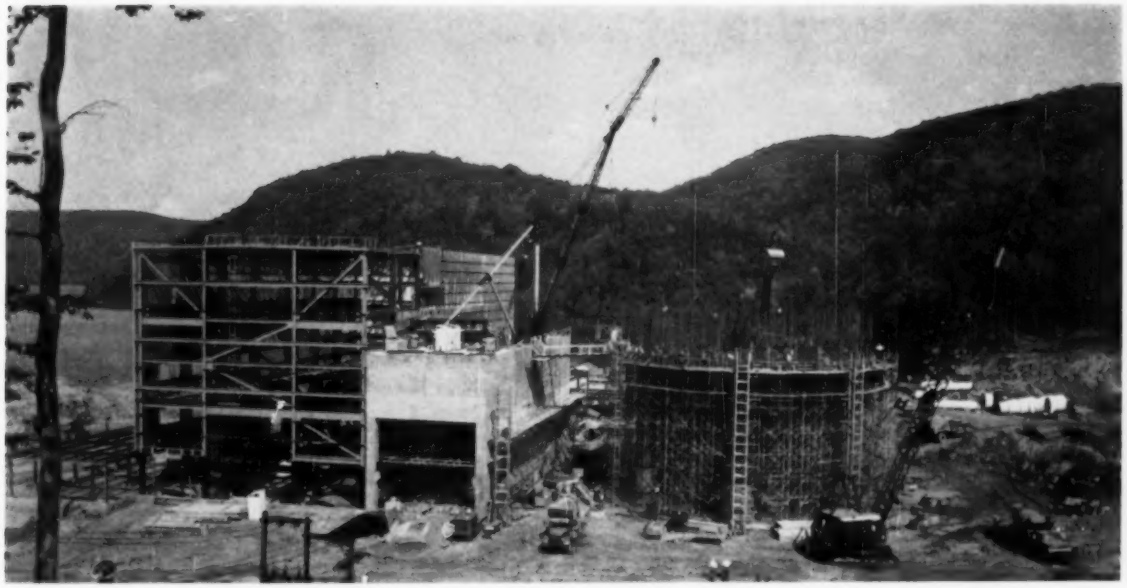
Conclusions

We certainly do not have 13-mil atomic power today that I am aware of, and we will be hard pressed to reach any 6 mil figure by 1980 as some optomistic estimates suggest. From a practical standpoint, it takes approximately four years to build and place in operation a large atomic power plant. The important points to note are that atomic power has an excellent chance of becoming competitive in the high cost areas in the next decade or two and that the growth will be gradual.

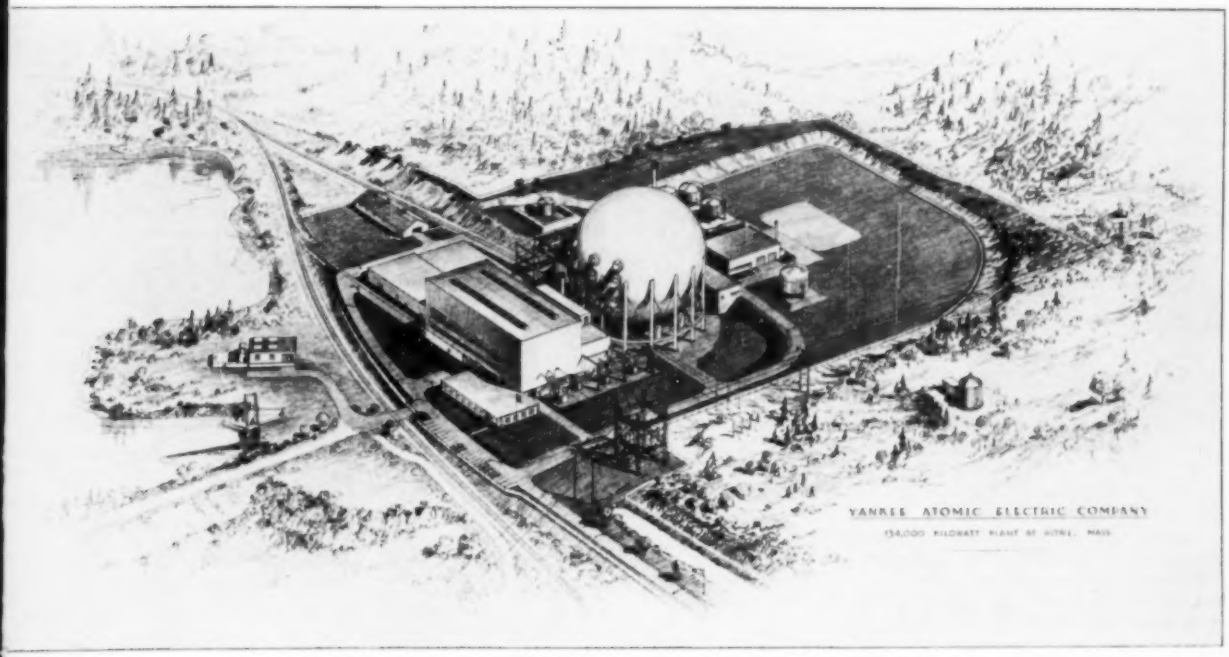
We have only mentioned the possibility of competitive power in the US. But the power situation is quite different in Europe and Japan. There, the cost of fossil fuel is much higher and rising rapidly; thus atomic power plants will be competitive sooner.

W. L. BUDGE is marketing manager, Atomic Power Dept., Westinghouse Electric Corp. This paper was presented at the 1958 Rocky Mountain Minerals Conference in Salt Lake City.

COMPETITIVE ?



Construction of the plant of Yankee Atomic Electric Co. is shown in a recent photograph, above. Below, is an artist's drawing of the completed 134,000 kw plant in 1960.



ALUMINIZED STEEL, properties and uses

by K. G. Coburn

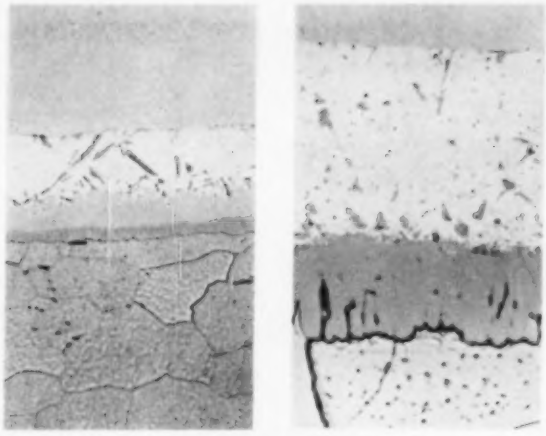


Fig. 1 (left) Coating on Armco's Aluminized Steel Type 1. Fig. 2 (right) Coating on Aluminized Steel Type 2. Mag 1000X, reduced to 85 pct.

A heat and corrosion resistant metal for coating steel sheet has captured the imagination of metallurgists for many years. Aluminum seemed to be at least a partial answer, but there were many problems to be overcome. Intensive research efforts appear to have led to the development of aluminum-coated steel suited for a wide range of applications.

ALUMINUM-COATED steel is well established in many product fields where superior heat and corrosion resistance is required. Good heat reflectivity with the strength of carbon steel are companion properties that widen the scope of application. Aluminum coatings may be applied to steel by spraying, electroplating, calorizing, cladding, or hot dipping methods. Of these, only the hot dip process has been developed commercially for sheet and coils over a broad range of gage and size. This was accomplished by Armco Steel Corp. when Aluminized Steel was introduced.

The material is produced by a continuous process, which utilizes similar equipment to that required for continuous galvanizing by the Armco method. This insures a tightly adherent coating, bonded to the steel base by an iron-aluminum alloy. Good coating uniformity is obtained on both sides of the sheet. Composition of the protective coating is closely controlled. The aluminum coating may be applied to a wide range of base metal analyses, including mild steel, copper-bearing steel, and low-alloy high-strength steel. Uniformity of base metal properties is assured by continuous processing, which combines annealing with the coating operation.

Aluminized Steel is manufactured in two grades of coating analysis. The first of these, known as Type 1, has a silicon-aluminum alloy coating best suited for high-temperature service or many applications where a combination of heat and corrosion is involved. The companion grade is identified as Type 2; its coating is applied from a bath of commercially pure aluminum. The notable property of Type 2 is its excellent resistance to atmospheric corrosion.

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The total weight of aluminum applied to both sides of the Type 1 sheet is approximately 0.5 oz per sq ft. This provides a coating thickness of about 0.001 in. of aluminum on each side, approximately equivalent in thickness to a 1.25 oz coating of zinc. Coating weight of the more atmospheric corrosion-resistant Type 2 grade is approximately 1.0 oz per sq ft or 0.002 in. of aluminum on each side.

The difference in coating weight is due largely to the effect of silicon. Silicon alters the surface oxide characteristics of the coating bath, causing an apparent change in the viscosity of aluminum. This effect, combined with inhibition of growth of the iron-aluminum alloy layer, results in thinner coatings. As thickness of the iron-aluminum bonding layer is reduced, the ability of the coating to stand deformation without peeling is significantly improved.

Coating structure

A typical microstructure of a silicon-aluminum coating applied by the Armco method is shown in Fig. 1. The dark gray acicular needles in the outer coating layer are a silicon-rich constituent. While these needles may contain a small percentage of iron and aluminum, they are principally silicon. The balance of the outer layer is aluminum solid solution with small dispersed islands of an iron-aluminum constituent. A two-phase structure exists in the iron-aluminum layer adjacent to the steel base. Iron content of these phases has not been determined independently, but total Fe averages 33.5 pct. X-ray diffraction indicates the phase next to the steel base to be FeAl, and the thicker part is believed to consist mainly of the binary intermediate phase $FeAl_3$.

Structure of the heavier nonalloyed coating on Type 2, is shown in Fig. 2. In the absence of silicon,

plates and stringers in the outer layer consist only of the iron-aluminum constituent in aluminum solid solution. The bonding layer next to the base metal is an iron-aluminum phase, probably FeAl, containing about 45 pct iron. The bonding layer develops greater thickness and contains higher iron than when effective amounts of silicon are present in the coating.

Coating adherence during fabrication

Type 1 Aluminized will withstand moderate forming, drawing and spinning operations without flaking or peeling of the coating. The material can be bent 180° over a diameter equal to twice its thickness without loss of bond between coating and base metal. However, more liberal bend radii are recommended when equipment will be operating at temperatures above 900°F.

Type 2 Aluminized will withstand moderate brake or roll forming operations and also can be bent 180° over a diameter equal to twice its thickness without separation of the coating. Type 2 can be spun or embossed but is not suitable for drawing operations.

Aluminum coatings on steel have better adherence when drawn in tension than when deformed under compression. When stressed in tension, the iron-aluminum phase next to the base metal develops vertical cracks without losing bonding to the base metal. Under severe compression, shearing stresses develop at the alloy-base metal interface which cause horizontal cracks in the alloy and separation of the coating from the steel.

Physical and mechanical properties

The properties shown below are typical of both types of aluminum-coated steel with a low carbon steel base.

Tensile strength, 55,000 psi
Yield strength, 40,000 psi
Elongation in 2 in., 28 pct
Rockwell "B" hardness, 66
Modulus of elasticity, 29,000,000
Coefficient of thermal expansion (10^{-6} in. per in. per °F), 6.7

Type 1 will withstand temperatures up to 900°F without discoloration, and up to 1250°F without destructive scaling. Above 900°F the coating begins to alloy with the steel base, forming a tight refractory layer of iron-aluminum alloy. Once formed, the dark grey alloy will not revert to its original bright appearance. The iron-aluminum alloy has excellent heat resistance and extends the maximum service temperature beyond the melting point of aluminum.

The unalloyed coating of Type 2 gives equal heat resistance up to 900°F, but it is not recommended for use above this temperature. Both types retain half their normal mechanical strength at 900°F.

At temperatures up to 900°F, aluminum-coated steel will reflect approximately 80 pct of incident radiant heat. This characteristic of the coating is retained after use, because of its resistance to detrimental oxidation and discoloration by heat.

Welding

Any of the standard methods of welding can be used to join aluminum-coated steel. Good joint strength is obtained when welding techniques are adapted to the properties of the material. Spot- or seam-resistance welding is recommended wherever practical, because less damage is done to the protective coating in the weld area. However, satisfactory welds are obtained with all types of fusion welding. Care must be exercised in controlling the aluminum oxide on the surface of the coating, as well as that formed during welding, or else it will tend to prevent steel-to-steel contact and increase weld porosity. This is done by using the proper welding flux or an inert gas shield.

Brazed joints can be made by using silicon-bronze rods. In this case the joint is between coated surfaces and should be used only when the strength of a steel-to-steel joint is not required. Soldering aluminum-coated steel presents the same problems as soldering aluminum, and no practical method has yet been developed.

Corrosion resistance

Atmospheric corrosion resistance of silicon-aluminum coatings is inferior to that of unalloyed aluminum coatings, and the silicon-bearing type is not usually recommended for atmospheric service. The Type 1 product is primarily a heat-resistant grade that gives good service in many applications requiring combined heat and corrosion resistance.

The heavier, unalloyed Type 2 coating is best suited for service where resistance to atmospheric corrosion is the primary consideration. On the basis of atmospheric exposure results to date, it is estimated that coating life in a mild industrial atmosphere will be at least three times that of commercial zinc coatings. Type 2 material has been exposed in the atmosphere at Middletown, Ohio, for 19 years and the coating is still intact. Galvanized sheet with a 1-oz coating was exposed at the same time. The zinc coating failed after seven years, and the base metal surface was 30 pct red-rusted at the end of 12 years.

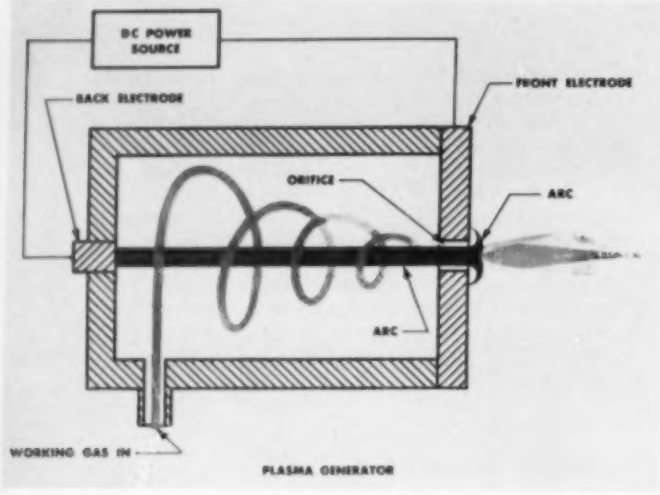
When exposed to the atmosphere, aluminum acquires a protective surface film. This sometimes causes the aluminum coating to become passive, so that galvanic protection is not provided at sheared edges. As a result, edge rust generally will appear after a short period of exposure.

Uses

The Type 1 heat-resistant grade is being widely used in kitchen range and laundry appliances, heat exchanger tubes, water heater and oven liners, element retainers and baffles, reflector plates, and automobile mufflers and tail pipes. A more recent use has been as a steel base for porcelain enameling.

Substantial quantities of the Type 2 atmospheric corrosion-resistant grade have been used for building panels, roof decking, silo roofs, air-conditioning enclosures, rolling door sections, corrugated industrial roofing and welded tubing.

Aluminum-coated steel is well-suited to a wide range of applications where the requirements are superior heat and corrosion resistance, good heat reflectivity, and strength at elevated temperatures. Standard production methods can be used in the fabrication and welding of these sheets. Maximum service temperature for Type 1 is several hundred degrees higher than allowable with zinc coatings. Corrosion life of Type 2 is estimated to be at least three times that of 1-oz galvanized in industrial atmospheres. Aluminum-coated steel has a strength and economic advantage over solid aluminum of the same thickness, and the steel base usually permits a reduction in thickness.



30,000 DEGREES WITH THE PLASMA JET

Expanding the frontiers of high-temperature, two US firms recently have announced the development of plasma-type torches capable of producing a jet of electrically neutral, partially ionized gas at extremely high temperatures. The result, a radically new method for fabricating shapes and applying coatings that will withstand temperatures above 5000°F.

A PROCESS that harnesses the highest controlled temperatures ever used in industry—up to 30,000°F—now makes possible the fast and accurate production of shapes and coatings from high-temperature materials that have been virtually unworkable by conventional means of the past.

What is it?

The key to the process is plasma—a stream of intensely hot, ionized gas. Such a jet is formed by passing a gas or a vapor through an electric arc. The arc is struck between a tungsten cathode and (usually) a water-cooled copper anode. Nitrogen, hydrogen, or argon are the gases normally used, but air can also be used with special shielding of the tungsten electrode.

The secret of the torch is not so much its total power consumption as its power concentration.

What are its applications?

The plasma jet can melt the toughest materials known to man without itself being consumed by the intense heat it generates. It has been used for some time in advanced research. Set up as a wind tunnel tool for either large or small units, the plasma jet can simulate speeds up to Mach 20 and reproduce conditions which a missile would encounter when re-entering the earth's atmosphere.

In a different field, the plasma jet can be significant in determining the physical changes that take place when solids, liquids, or certain types of gases are passed through the heat of the arc.

Production applications of the plasma jet are enormous and considerable time will be required to explore them all. For the first time engineers have the possibility of effectively coating metals and other materials with refractory metals and compounds, such as borides, carbides, nitrides, silicides, and oxides. The inert jet offers a completely uncontaminated spraying environment which oxidizes neither the base nor the sprayed material.

Coatings made with the plasma jet powder torch are unique. They have excellent bonding capabilities to most base materials, including some reinforced plastics, graphites, and carbons. The coatings are dense, usually laminar in structure, and may be finished to a thickness below 1.5 μ in.

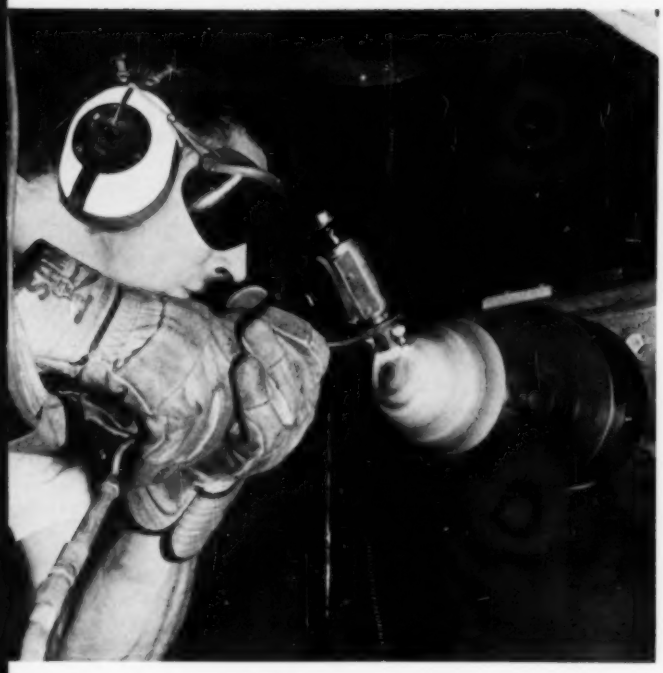
Plasma-jet coatings have a wide area of application in the production of refractory parts, such as crucibles and molds for high-temperature materials. Plasma-jet coatings have been used in advanced designs of solid-fuel rocket engines. Nozzles for these rockets are subject to temperatures up to 5500°F and exhaust velocities up to 5000 ft per sec. Few materials can withstand such conditions. But graphite coated with metallic tungsten by means of the plasma jet has apparently solved the problem.

Another application of the plasma jet is in making shapes of refractory materials. There are several distinct advantages gained in forming these parts with the plasma jet. They can be made structurally sound without resorting to heavy walls. The thinnest practical crucible wall understood to have been made by other processes is 0.125 in., but plasma-jet-formed crucible wall thicknesses on the order of 0.010 to 0.060 can be achieved. In the electronics industry parts for large vacuum tubes can be readily and economically formed by the plasma jet from any desired refractory materials.

The range of applications for refractory coatings and shapes in all industries is considered to be extremely wide.

The coating process

The coating material, prepared either in wire or powder form, is passed through the arc inside the torch. Because of the temperature above 15,000°F, the coating material is converted into a fluid or plastic state. It is carried out of the torch by gases flowing at velocities up to 10,000 mph to be deposited on the part being made or plated with such force that a firm bond results. The coating is cooled at once by sprays of carbon dioxide to form a hard, dense surface that bonds perfectly.



Plasma Arc torch coats nose cone with tungsten (above), while Plasmatron slices through ⅛-in. stainless steel sheet (right).

Making parts

In order to make a part by the plasma jet, a mandrel is first prepared to the precise internal diameter of the part to be made. Once the mandrel is chucked, the torch applies the selected material and moves back and forth over the length of the part, maintaining a 90° angle to the surface being coated. When the proper thickness has been reached, the jet is stopped and the mandrel is leached out. Brass is often used and then dissolved in nitric acid. Where acid attacks the coating material, an aluminum mandrel is made and then leached out with caustic. There is no reason, consistent with parts accuracy, why other mandrel materials, including plastic, cannot be used.

Once made, parts are given a moderate heat treatment to improve density and other physical properties. They may or may not require additional polishing or grinding, depending on their applications.

On the history

The principle of the plasma jet has been known for some time. A primitive plasma jet was actually devised 35 years ago by Gerdien in Europe. R. M. Gage of Linde's Speedway Laboratories provides us with information on the history of the plasma jet:

"Since the Geriden arc jet was first devised, this and other experimental plasma have been studied in Europe, mainly Germany, by Peters, Maecker, and others. Temperatures up to 50,000°K have been produced by making the water vortex so as to squeeze the arc into a small channel. Until recently such devices have been of academic interest only, partly because the carbon electrodes are rapidly consumed, and partly because water vapor is unacceptable in most applications.

"In the United States, beginning during World War II, the tungsten inert-gas process, using conventional unconstricted arc, revolutionized welding, because it provided long life, constant characteristics, and atmosphere control."

In recent years several firms have been at work on the plasma jet ideas; these include Linde Co., General Electric Co., Thermal Dynamics Corp., and Giannini Plasmadyne Corp.

Linde's Plasma Arc torch

Linde Co., div. of Union Carbide Corp., has been producing experimental coatings with its Plasma Arc torch for the past five years, and during the past two years it has offered Plasma Arc torch coatings to industry on a commercial basis. Late in 1955 Linde and Plasmadyne introduced the modern plasma jet for cutting aluminum.

Linde provides us with some general information on the modern plasma jet and its Plasma Arc:

There are two basic types of modern plasma jet devices: transferred and non-transferred arc. Using the former, both the arc and the gas continue along together after leaving the nozzle. With the latter, the arc is forced into and perhaps through the nozzle by the flow of gas; the arc ends on the nozzle and the hot gas continues alone. The transferred arc is used for metal cutting; the non-transferred arc torch is the basis for arc plating.

The electric arc column is forced to operate within a small diameter tube through which go both a part of the arc and a flow of gas. By making the nozzle small, relative to the normal unconfined arc, a substantial part of the nozzle is filled by the arc. Thus, a good portion of the gas flow through the nozzle must also be through the arc.

There are four major advantages to constricting nozzles:

a) **Arc flame stability**—The plasma from a constricting nozzle goes in the direction it is pointed, even at relatively small gas flows;

b **Concentration of power**—This is most important in metal cutting where it is desirable to make the kerf as narrow as possible;

c) **Concentration of momentum**—The value of this is apparent in accelerating metal particles to be plated or in ejecting molten metal from a cut;

d) **Heating of gas and powder**—Material passed around an arc will be heated very little, as compared with material forced through an arc.

But how is the nozzle material of Plasma Arc torch able to withstand arc temperatures: The answer is that it doesn't. In a properly designed torch, the arc column does not touch the nozzle. Surrounding the arc column proper and adjacent to the nozzle wall is an annular layer of cooler gas having a very steep radial temperature gradient. At low gas flows through the nozzle, the cool layer results from the radial flow of heat to the nozzle. At higher gas flows, much of this radially flowing heat is swept out by the flow of gas before reaching the nozzle wall.

Giannini's Plasmatron

Giannini Plasmadyne Corp. has had its plasma jet, called the Plasmatron, under development for the past three years. Its coating technique, called Plasma Spray, was released last July. The Plasma Spray creates temperatures up to 25,000°F. It reaches velocities of 13,000 ft per sec, but the jet is easily handled.

The plasma generator employs thermal and magnohydrodynamic effects to put the plasma under pressure and increase its density. The arc is struck inside a small cylindrical chamber and carried outside the chamber.

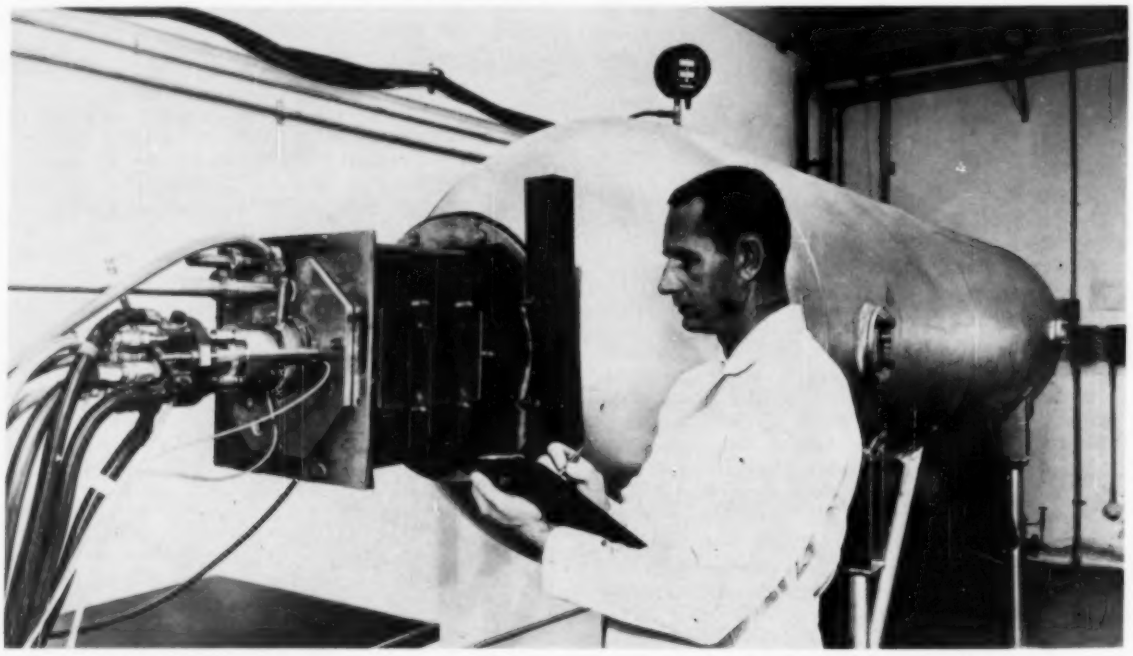
One end of the chamber is an electrode—a flat plate of tungsten or other conducting metal—perforated at its center to provide an orifice for the plasma jet. Cooling is provided by a jet of gas injected tangentially into the water-cooled chamber.

The current in the discharge tends tc concentrate in the hotter central region of the plasma. This increase in current density, by what may be called a thermal pinch effect, brings a further increase in temperature and conductivity. When the current density in the center of the discharge reaches a high enough value, the second—or magnetic—pinch takes over. The combination of electromagnetic forces and high pressure now developed in the chamber, ejects the plasma from the orifice in a 6-in. long beam of highly excited particles up to ½ in. in diam.

Summary

The Plasmatron and the Plasma Arc torch have opened new doors in the metals field. These devices are not the first nor the last developments of their kind. Already Linde is working on an experimental High Current DC Arc Torch to explore problems involved in using power above 10,000 amp. This will result in concentrations of power equivalent to 3 megawatts per sq in.—equal to putting the total output of the largest electrical generator into an area 6 in. sq. Conversely, Giannini is about to release a new miniature hand-held spray gun, weighing 1 lb 6 oz and capable of depositing refractories and other materials at speeds equivalent to paint-spray techniques.

As the space age continues to require ways and means of working with ever-increasing temperatures, research and development men must continue to solve the improbable and harass the impossible. Gabriel Giannini has analyzed today's trends in these words: "The climb up the temperature scale that has now begun will bring opportunities still uncharted. It will teach us much about processes in the stars and give us a means of manipulating matter and energy in ways we have not yet imagined."



A standard Plasmatron plasma jet head, coupled to an evacuated chamber, can produce thermal effects corresponding to those encountered at Mach 20.

METALLURGICAL SOCIETY STUDIES SCOPE OF TECHNICAL COMMITTEES

Metallurgy, in this fast moving age of technological development, is probably advancing more rapidly than any other field. Thus, the organization of The Metallurgical Society of AIME must be adequate and sufficiently flexible so as to promote competently the expanding professional interests of its members. For this reason the question arose whether the present technical committees adequately assist in fulfilling the objectives of The Metallurgical Society . . . "to promote the advancement of metallurgical knowledge and the advancement of the metallurgical profession."

Several years ago, or perhaps even one year ago, this question might have received a negative answer, but since then changes have taken place, and are still taking place in The Metallurgical Society. These are largely in the form of extensive reorganization of technical committees in the three divisions of The Metallurgical Society. The overall task of examining the technical committee structure was assigned to the Programs Committee of which J. F. Elliott is chairman. But the study of this matter is one of continual review so that further changes in the scope and number of technical committees can be expected.

For the Society as a whole, the Programs Committee has a proposal resulting from the report of the Extractive Metallurgy Div. that consideration be given to forming Society, rather than division, committees in the following areas: (1) marketing and economics in the metals industries, (2) process design and control, and, (3) refractories. Should such a Society Refractories Committee be formed, for example, it is presumed that division refractories committees would be discontinued.

Presented on the following pages is a report on the new committee structure of the Institute of Metals Div. and the Iron and Steel Div. The report of the Extractive Metallurgy Div. presents the reorganization of the division technical committees, effective following the 1959 Annual Meeting.

I. Technical Committees of Extractive Metallurgy Div.

With the objectives of broadening the coverage of new developments in extractive metallurgy, the Extractive Metallurgy Div., in February, 1958, appointed an *ad hoc* committee to study the structure of technical committees. Serving on this committee were H. H. Kellogg, Chairman, A. E. Lee, Jr., R. Schuhmann, Jr., and J. D. Sullivan. Their report, approved by the Division's Executive Committee in August, recommended the creation of two new technical committees, and the change in name of several existing committees. As a result, the Extractive Metallurgy Div. will have 11 technical committees, when the reorganization becomes effective in February, 1959.

A portion of the Committee report follows:

"The aim of the EMD committee organization should be to provide committees that cover the subject matter of extractive metallurgy in sufficient breadth that all metals, processes, and disciplines receive attention commensurate with their importance. Carried to its extreme, this aim might call for separate committees for each of the 70 or 80 metals, and for each of the 100 or more separate processes used in extractive metallurgy. However, a large number of committees would destroy the unity of EMD and cause serious organization problems.

"As far as the subject matter covered by the technical committees is concerned, we believe that the present system of horizontal-vertical overlapping of *commodity* and *functional* committees is a good one and should be retained. We are opposed to a committee structure that imposes rigid compartmentalization on the subject matter. We feel that technical progress and research productivity will be greatest in new fields which will not fall directly into the traditional divisions of the past. Overlapping commodity and functional committees permit retention of the traditional groupings of common interest (Pb-Zn, Cu-Ni, etc.) and still provide the flexibility inherent in the functional approach to subject matter.

"Finally, we recommend a procedure for regular review of the committee structure of EMD in recognition of the fact that the subject matter of extractive metallurgy is ever-shifting in emphasis, so that the new committees may become necessary, or existing ones unnecessary."

The Committee also defined extractive metallurgy as the "science and art of producing metals. It begins with the processing of ores, concentrates, or industrial by-products of such metals from that point where up-grading by physical separation ends and chemical conversion begins. It ends with the production of metals or metallic compounds of sufficient purity to permit their use without further refining in the manufacturing arts. The science and art of producing includes, but is not limited to, such activities as research, engineering, production, management, economics, and education."

Listed below are the technical committees of the Extractive Metallurgy Div. All of these committees participate in program planning for the AIME Annual Meeting, and some will assist in programming for AIME regional meetings and technical conferences.

A. Commodity Committees

1. **Lead, Zinc, and Tin Committee**
(L. W. Hanley, Chairman of present Lead and Zinc Committee)

Primarily concerned with lead, zinc, and tin. Coverage also includes related metals usually recovered as by-products of extractive processes for lead, zinc, and tin. A suggested, but not restricted, list of these metals is: Pb, Zn, Sn, Sb, As, Bi, Cd, Ge, In, and Tl.

2. **Copper, Nickel and Precious Metals Committee**
(R. J. Stevens, Chairman of present Reduction and Refining of Copper and Nickel Committee)

Primarily concerned with copper, nickel, and precious metals. Its coverage also includes related metals usually recovered as by-products of extractive processes for copper, nickel, and precious metals. A suggested, but not restricted, list of these metals is: Cu, Ni, Au, Ag, Co, Ir, Os, Pd, Pt, Rh, Ru, Se, and Te.

3. **High Temperature Metals Committee**
(M. A. Steinberg, Chairman of present Titanium, Uranium, and Uncommon Metals Committee)

Primarily concerned with high-temperature metals. A suggested, but not restricted, list of these metals is: Be, B, Cr, Cb, Hf, Mn, Mo, Re, Si, Ta, Tc, Ti, W, V, and Zr.

4. **Uranium, Rare Earths, and Minor Metals Committee**
(M. A. Steinberg, Chairman of present Titanium, Uranium and Uncommon Metals Committee)

A suggested, but not restricted, list of the metals by this committee is: U, transuranics, rare earths, Ac, At, Fr, La, Hg, Po, Pa, Ra, Sc, Th, and Y.

5. **Light Metals Committee**
(W. S. Peterson, Chairman of present Aluminum and Magnesium Committee)

Primarily concerned with aluminum, magnesium, and other light metals. A suggested, but not restricted, list of these metals is: Al, Mg, Ba, Ca, Cs, Ga, Li, K, Rb, Na, and Sr.

B. Functional Committees

1. **Pyrometallurgy Committee**
(G. H. Turner, Chairman)

Pyrometallurgy broadly encompasses all metallurgical processes in which elevated temperatures are employed, with the exception of fused-salt electrolysis. In areas of overlay with the various commodity committees of EMD, this committee will concentrate its activities on papers that fall in one or more of the following categories:

a) General aspects of pyrometallurgy such as: means of obtaining high temperatures, measurement and control of high temperatures, characteristics of particular fuels of reducing agents, and furnace design;

b) Study of particular pyrometallurgical processes as unit processes. A particular process, such as the blast furnace, vacuum retort, fluid-bed chlorinator, etc., may be analyzed and studied as a process type or unit. Such studies are the proper concern of this Committee and should be encouraged;

c) New pyrometallurgical processes.

2. **Hydrometallurgy Committee**
(W. M. Fassell, Jr., Chairman)

Hydrometallurgy broadly encompasses the processes whereby reactions in aqueous solution are utilized for the extraction or refining of metals. The two main operations of hydrometallurgy are dissolution (leaching) of metal values from ore, concentrate, or other intermediate substance, and recovery of metal values from solution by precipitation, ion exchange, solvent extraction, etc. In areas of overlap with the various commodity committees of EMD, this Committee will concentrate its activities on papers that deal primarily with the hydrometallurgical operation, its understanding, and control.

3. **Electrolytic Processes Committee**
(W. R. Opie, Chairman)

Studies of cell design, electrode reactions, overvoltage, electrical transport phenomena, form of electrode deposits, and effect of temperature, electrolyte composition, and current density on process results are the prime concern of this Committee. In areas of overlap with the various commodity committees of EMD, this Committee shall concentrate its activities on papers that deal primarily with the electrolytic operation, its understanding, and control.

4. **Physical Chemistry of Extractive Metallurgy Committee**
(W. A. Krivsky, Chairman)

Physical chemistry underlies all extractive metallurgy processes. This Committee will concentrate its activities, however, on papers in which the prime concern is the development of new physical chemical data, or the direct application of such data to understanding of process behavior. Following is a suggested, but not restrictive, list of subject matters considered to be primarily physical chemistry: phase and chemical equilibria, activity and structure of solutions, thermodynamic properties, chemical kinetics, diffusion, and surface chemistry and physics.

5. **Refractories Committee**
(A. P. Thompson, Chairman)

This Committee is interested in the operating behavior of refractories. It will also seek new information on the understanding of refractory attack (refractory-metal and refractory-slag equilibria, kinetics of refractory reaction, etc.), and the physical and mechanical properties of refractory bodies.

6. **Nuclear Fuel Reprocessing Committee**
(M. A. Steinberg, Chairman of present Titanium, Uranium, and Uncommon Metals Committee.)

The reprocessing of metallic fuel elements is a special application of metal refining. The nature of the alloys to be refined, the problem of handling dangerous radioactivity, and the special problems of acceptable impurity limits are all peculiar to nuclear fuel reprocessing, and justify a separate committee to handle this subject. The refining methods that may be used, however, bear close resemblance to refining methods for the common metals. The Committee will seek papers on all aspects of the problem from theory to operating results.

II. Technical Committees of Institute of Metals Div.

Following reorganization of The Metallurgical Society in 1957, the Institute of Metals Div. took immediate action along these lines with reference to committee structure:

1) The number of technical committees was increased from five to eighteen;

2) A new committee with the unusual name, *Committee on Scope of Technical Committees,* was established and;

3) A meeting ground for chairmen of technical committees was provided in a Council of Technical Committees.

The Committee on Scope of Technical Committees had understood its function as maintaining a "continuous review of the scope of activities and the charter of the technical committees." The Committee was commissioned to report annually on the extent to which the scope of existing committees fulfills the objectives of the Division and the Society.

The Committee, under the chairmanship of J. H. Jackson, completed its survey and reported at the Fall Meeting of The Metallurgical Society. A summary of this report, "Scope and Activities of Technical Committees of the Institute of Metals Div." follows:

1. **Chemistry and Physics of Metals Committee**

(J. J. Gilman, Chairman)

Fall and Annual Meeting Sessions.

Basic scientific understanding of the behavior of metal systems. Includes the chemical, mechanical, electrical, and magnetic properties of metals.

2. **Corrosion-Resistant Metals**

(T. N. Rhodin, Chairman)

National Conference on Stress Corrosion Fracture, Mellon Institute, April 2 and 3, 1959.

Concerned with those physical metallurgical properties of a metal which are influenced by interaction with environment, such as aqueous solution, nonaqueous liquids, vapors, liquid metals, fused salts, and gas atmospheres.

3. **Electrical and Magnetic Metals**

(J. J. Becker, Chairman)

Fall Meeting sessions. Joint meetings with other societies.

Relationships between structure, processing, and properties of materials intended for electrical or magnetic application, excepting semiconductors.

4. **Ferrous Metallurgy**

(D. J. Blickwede, Chairman)

Planning session in anisotropy of steels session at Fall or Annual Meeting.

Physical metallurgy of ferrous metals, including the structure, mechanical and physical properties as they are affected by equilibria, reaction kinetics, diffusion, etc., and those aspects of process metallurgy (iron and steel making, rolling, forming, etc.) which influence the structure and properties of ferrous metals.

5. **Heat Treating**

(R. D. Chapman, Chairman)

Heat treatment of ferrous and nonferrous metals with emphasis on equipment and atmospheres.

6. **High-Temperature Alloys**

(N. J. Grant, Chairman)

Fall and Annual Meeting sessions and special conference at Los Angeles, May 5, 1958.

High-temperature deformation and fracture, high-temperature testing and alloy development, and structural studies relating to high temperature.

7. **Melting and Casting**

(W. S. Pellini, Chairman)

Symposium on Liquid Metals with ISD and EMD, Pittsburgh, April 27 to 30, 1959.

Aspects of melting and casting not normally covered by Open-Hearth, Electric Furnace, or AFS. Basic aspects and their applications, such as the nature of liquid metals, mechanism of solidification, advanced melting methods, advanced molding methods, liquid flow of metals, defect deformation in castings, and relationship of casting variables on properties of metals.

8. **Joining**

(E. F. Nippes, Chairman)

9. **Non-Ferrous Metallurgy**

(F. H. Wilson, Chairman)

Fall Meeting session, 1959.

Problems related to the production of Al, Cu, Pb, Mg, Ni, Zn, and precious metals and their alloys.

10. **Nuclear Metallurgy**

(J. A. Fellows, Chairman)

Fall and Annual Meeting sessions on metallurgy of nuclear materials.

11. **Physical Metallurgy**

(H. W. Paxton, Chairman)

Fall and Annual Meeting sessions (beginning soon). Planning a 2-day meeting in 1960.

The relationship between the structure of metallic materials and their properties which are of engineering interest.

12. **Powder Metallurgy**

(G. L. Bibbins, Chairman)

Fall and occasional Annual Meeting sessions and special conferences as with MPI in New York, June, 1960.

Foster a scientific interest in powder metallurgy. Interest students at various levels, as well as metallurgists and other engineers, in powder metallurgy. Provide a medium for dissemination of information in the field of powder metallurgy.

13. **Refractory Metals**

(J. J. Harwood, Chairman)

Fall Meeting sessions with High-Temperature Committee in 1958.

Methods of preparation and purification; physical metallurgy, consolidation, fabrication, processing, oxidation and surface reaction, and surface protection and application of those metals having melting points above 3400°F such as Rh, Cb, Ir, Re, Mo, Os, Ta, W, etc. (plus Cr).

14. **Semiconductors**

(W. C. Hittinger, Chairman)

Fall and Annual Meeting sessions and special conference at Boston, August 31 to September 2, 1959 on metallurgy of semiconductors.

15. **Shaping and Forming**

(E. S. Rowland, Chairman)

Fall and/or Annual Meeting beginning in 1959 or 1960.

Mechanical analysis, materials properties during and after working surface or boundary properties (lubrication), and workability tests, as applied to rolling, extrusion, deep drawing, wire and tube drawing, tube forming, stretch forming, spinning, embossing, coining, forging, pressing (blanking, piercing), mashing, and grinding.

16. **Structural Materials**

(J. H. Rizley, Chairman)

Structural applications of materials, rather than basic properties of materials. Physical and mechanical properties of all structural metallic materials primarily as they affect structural applications.

17. **Surface Treatment**

(W. R. Meyer, Chairman)

Properties of coatings in specific applications, such as solderability, electrical conductivity, heat radiation, room temperature and high-temperature corrosion resistance, and resistance to oxidation. Comparisons of various processes, such as phosphating, chromating, anodizing, and chromizing in their relationship to corrosion resistance or any of the properties mentioned above. Discussion of processes of coating metals not normally considered by the metal finishing societies, for example, flame spraying, or coating, diffusion coatings, and vacuum deposition.

18. **Titanium**

(A. L. Rustay, Chairman)

Fall Meeting seminars on engineering aspects of titanium.

III. Technical Committees of Iron and Steel Div.

The Iron and Steel Div. has not yet undertaken a comprehensive study of the scope of its technical committees, with a definition of the objectives of each committee. Existing technical committees are reviewed below, with notes on activities of each committee:

1. **Acid Converter and Basic Oxygen Committee**

(A. B. Wilder, Chairman)

Meets annually in spring for plant trip and technical symposium. Also periodically sponsors sessions at AIME Annual Meetings.

Originally the Bessemer Steel Committee, the new name change reflects coverage of the modern oxygen steelmaking process. Membership includes representatives from all US and Canadian companies in the field.

2. **Blast Furnace, Coke Oven, and Raw Materials Committee**

(J. W. Duncan, Chairman)

Meets annually in April for 3-day conference covering blast-furnace and coke-oven theory and practice, coal preparation, raw materials, and by-products. Publishes proceedings.

This Committee is now considering enlarging its organization to include local sections in areas where blast furnaces are concentrated.

3. **Electric Furnace Committee**

(A. C. Ogan, Chairman)

Meets annually first week of December for 3-day conference covering electric-furnace operations for ingots, castings, ferroalloys, and calcium carbide. Publishes proceedings.

Name was changed in 1958 from *Electric Furnace Steel Committee* to reflect enlarged scope which now includes other uses of electric arc furnace: ferroalloys, calcium carbide, special refractories, and abrasives.

4. **Mechanical Working Committee**

(R. D. Hindson, Chairman)

Sponsors separate technical conferences and periodically sponsors sessions at AIME Annual Meetings.

Committee has organized Technical Conference for January 21, 1959, Del Prado Hotel, Chicago, on *Factors Affecting Shape and Surface Texture of Hot and Cold Rolled Products.*

5. **National Open Hearth Steel Committee**

(V. W. Jones, Chairman)

Meets annually in April for 3-day conference covering basic and acid operations, refractories, and masonry, combustion, operating metallurgy, and cold metal and basic foundry operations. Publishes proceedings.

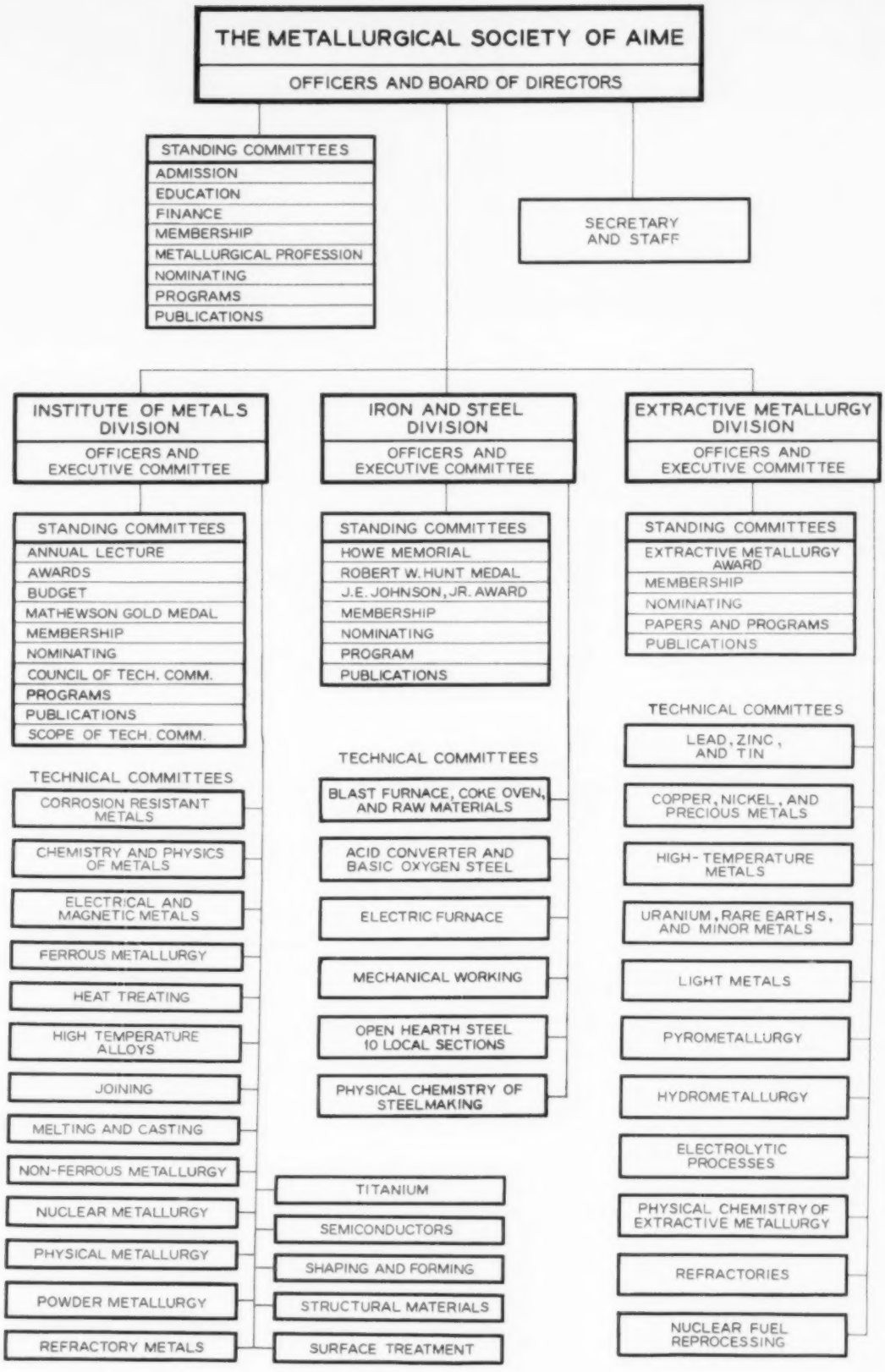
Has 10 organized local sections in steelmaking cities, each with own technical program. The National Committee, with its own funds, sponsors L. F. Reinartz Scholarship at Carnegie Institute of Technology and publishes occasional books on steelmaking.

6. **Physical Chemistry of Steelmaking Committee**

(B. R. Queneau, Chairman)

Committee sponsors sessions at AIME Annual Meetings, Electric Furnace Conference, and National Open Hearth Steel Conferences. Also, has sponsored own Technical Conference on *Quality Requirements for Super-Duty Steels.*

Purpose defined as promoting "the advancement of the science of iron and steelmaking and shall also be responsible for the dissemination of this knowledge in industry." Committee is now writing handbook on electric-furnace steelmaking, as a sequel to its earlier book, *Basic Open Hearth Steelmaking.*


THE METALLURGICAL SOCIETY OF AIME
OFFICERS AND BOARD OF DIRECTORS
STANDING COMMITTEES
ADMISSION
EDUCATION
FINANCE
MEMBERSHIP
METALLURGICAL PROFESSION
NOMINATING
PROGRAMS
PUBLICATIONS
SECRETARY AND STAFF
INSTITUTE OF METALS DIVISION
OFFICERS AND EXECUTIVE COMMITTEE
STANDING COMMITTEES
ANNUAL LECTURE
AWARDS
BUDGET
MATHEWSON GOLD MEDAL
MEMBERSHIP
NOMINATING
COUNCIL OF TECH. COMM.
PROGRAMS
PUBLICATIONS
SCOPE OF TECH. COMM.
TECHNICAL COMMITTEES
CORROSION RESISTANT METALS
CHEMISTRY AND PHYSICS OF METALS
ELECTRICAL AND MAGNETIC METALS
FERROUS METALLURGY
HEAT TREATING
HIGH TEMPERATURE ALLOYS
JOINING
MELTING AND CASTING
NON-FERROUS METALLURGY
NUCLEAR METALLURGY
PHYSICAL METALLURGY
POWDER METALLURGY
REFRACTORY METALS
TITANIUM
SEMICONDUCTORS
SHAPING AND FORMING
STRUCTURAL MATERIALS
SURFACE TREATMENT
IRON AND STEEL DIVISION
OFFICERS AND EXECUTIVE COMMITTEE
STANDING COMMITTEES
HOWE MEMORIAL
ROBERT W. HUNT MEDAL
J.E. JOHNSON, JR. AWARD
MEMBERSHIP
NOMINATING
PROGRAM
PUBLICATIONS
TECHNICAL COMMITTEES
BLAST FURNACE, COKE OVEN, AND RAW MATERIALS
ACID CONVERTER AND BASIC OXYGEN STEEL
ELECTRIC FURNACE
MECHANICAL WORKING
OPEN HEARTH STEEL 10 LOCAL SECTIONS
PHYSICAL CHEMISTRY OF STEELMAKING
EXTRACTIVE METALLURGY DIVISION
OFFICERS AND EXECUTIVE COMMITTEE
STANDING COMMITTEES
EXTRACTIVE METALLURGY AWARD
MEMBERSHIP
NOMINATING
PAPERS AND PROGRAMS
PUBLICATIONS
TECHNICAL COMMITTEES
LEAD, ZINC, AND TIN
COPPER, NICKEL, AND PRECIOUS METALS
HIGH-TEMPERATURE METALS
URANIUM, RARE EARTHS, AND MINOR METALS
LIGHT METALS
PYROMETALLURGY
HYDROMETALLURGY
ELECTROLYTIC PROCESSES
PHYSICAL CHEMISTRY OF EXTRACTIVE METALLURGY
REFRACTORIES
NUCLEAR FUEL REPROCESSING

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PAST-PRESIDENT—GROVER J. HOLT

PRESIDENT-ELECT—HOWARD C. PYLE

VICE-PRESIDENTS—E. C. BAGSON, L. E. ELKINS, J. L. GILLSON, J. C. KINNEAR, JR., R. V. PIERCE, A. W. THORNTON

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SECRETARY—ERNEST KIRKENDALL

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FIELD SECRETARY & ASS'T. SECY.—R. E. O'BRIEN, 707 NEWHOUSE BLDG., SALT LAKE CITY 1, UTAH

AIME NEWS

Changes in Selection of AIME and Metallurgical Society Presidents

Reorganization of AIME has brought about a significant change in the method of electing the President of AIME. Instead of a nominating committee organized along geographical lines and representing AIME Sections, each Society has been given the task of selecting the President every third year. During 1959, The Metallurgical Society will assume, for the first time, the responsibility of nominating a President-Elect of AIME. This job falls to the Society's Nominating Committee.

The Society's Nominating Committee

Who are they? . . . nine in all, three from each division. For 1959 to 1960 Walter R. Hibbard, Jr. will serve as Chairman. Also representing the Institute of Metals Division, are W. J. Harris, Jr. and David Swan. From the Extractive Metallurgy Division are J. C. Kinnear, Jr., R. R. McNaughton, and P. T. Stroup. The Iron and Steel Division I is represented by H. B. Emerick, J. S. Marsh, and C. E. Sims.

What are their tasks? These are explained in detail in the excerpt from the Bylaws of The Metallurgical Society which is printed on page 49. In addition to nominating a President-Elect of AIME every third year, the Nominating Committee must also select Metallurgical Society representatives for the AIME Board of Directors (two Directors per year for three-year terms, two Vice Presidents from our total representation of six to serve one-year terms, and every third year, nominee for President-Elect). Furthermore, the Nominating Committee is charged with the responsibility of selecting the Vice President of The Metallurgical Society; he is automatically President-Elect of the Society. The names and biographies of all nominees are published each year in the July issue of JOURNAL OF METALS.

Although provisions of the bylaws provide for other nominations, members may also wish to forward suggested names to any member of the Society's Nominating Committee or to the Chairman,

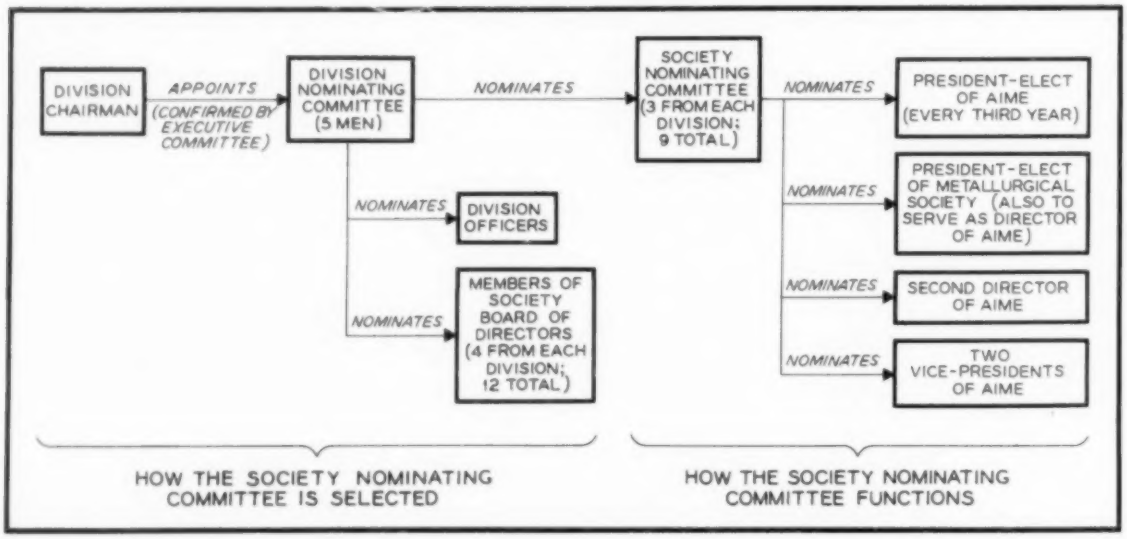
Dr. Walter R. Hibbard, Jr., Manager, Alloy Studies Research, General Electric Company, Schenectady 9, New York

You are encouraged to do so.

How the Society's Nominating Committee Is Chosen

Each division, through its division nominating committee, chooses three men for the Society's Nominating Committee. (The names of the above nine men were published in the July 1958, JOURNAL OF METALS.) The incoming President of the Society then designates one of the nine as Chairman.

How, then, do the division nominating committees function? The bylaws of each of the three divisions


DIVISION CHAIRMAN
APPOINTS (CONFIRMED BY EXECUTIVE COMMITTEE)
DIVISION NOMINATING COMMITTEE (5 MEN)
NOMINATES
DIVISION OFFICERS
NOMINATES
MEMBERS OF SOCIETY BOARD OF DIRECTORS (4 FROM EACH DIVISION; 12 TOTAL)
NOMINATES
SOCIETY NOMINATING COMMITTEE (3 FROM EACH DIVISION; 9 TOTAL)
NOMINATES
PRESIDENT-ELECT OF AIME (EVERY THIRD YEAR)
NOMINATES
PRESIDENT-ELECT OF METALLURGICAL SOCIETY (ALSO TO SERVE AS DIRECTOR OF AIME)
NOMINATES
SECOND DIRECTOR OF AIME
NOMINATES
TWO VICE-PRESIDENTS OF AIME
HOW THE SOCIETY NOMINATING COMMITTEE IS SELECTED
HOW THE SOCIETY NOMINATING COMMITTEE FUNCTIONS

specify that the chairman of division shall appoint a nominating committee consisting of five members, subject to the approval of the division executive committee. The Institute of Metals Division bylaws further specify that at least three shall be past-chairmen of the Division. All bylaws state that the division nominating committee shall nominate candidates for division offices, and in addition, candidates for the Society's Board of Directors and Society's Nominating Committee. The names of all nominees are published in the July JOURNAL OF METALS, and provisions are made for additional nominations up to August 15.

Special Sessions Set For Annual Meeting of Metallurgical Society

The Metallurgical Society will feature special sessions on plutonium and beryllium at the 1959 AIME Annual Meeting, to be held at the St. Francis Hotel in San Francisco, February 15th to 19th. A symposium on beryllium is scheduled for Monday afternoon, February 16th, at which A. R. Kaufmann of Nuclear Metals Inc. will serve as chairman. Among the thirteen papers on beryllium will be papers on the brazing, welding, casting, rolling, forging, and extrusion of beryllium.

A two-session symposium on plutonium will be held on Monday afternoon and Tuesday morning, February 16th and 17th. The first session will be devoted to the extractive metallurgy of plutonium; the second session on the physical metallurgy of plutonium. These sessions are under the joint sponsorship of the Extractive Metallurgy Division and the Institute of Metals Division.

The Extractive Metallurgy Division has arranged for two sessions to be held jointly with the Minerals Beneficiation division on chemical processing of nickel and the chemical processing of uranium. The Extractive Metallurgy Division has also planned special sessions on chlorination processes and on rare earths.

The Iron and Steel Division will conduct sessions on iron ore reduction, iron blast furnace engineering, basic oxygen steelmaking, steelmaking technology, the basic science of steelmaking, and pyrometallurgical processes. The last session is jointly sponsored with the Extractive Metallurgy Division. Of particular interest will be a paper on the experience of Jones & Laughlin Steel Corp. with the operation of their basic oxygen furnace, and a paper giving the analytical results of the nitrogen quenching of a U.S. Bureau of Mines experimental blast furnace.

The Institute of Metals Division is conducting symposiums on *Interfaces and Surfaces, Direct Observations of Dislocations, Scale Effects on Properties, and Alloy Strengthening at Elevated Temperatures.* In addition, eight sessions will be devoted to the presentation of some sixty papers based on the submission of abstracts. The complete technical program appears on page 57 of this issue.

The Institute of Metals Division lecturer on Wednesday, February 18th, will be Professor Frederick Seitz, University of Illinois, who will speak on *The Effects of Irradiation Upon Metals.* The Howe Memorial Lecture of the Iron and Steel Division will be presented on Tuesday morning, February 17th, with Clarence E. Sims of Battelle Memorial Institute giving his paper on *The Nonmetallic Constituents of Steel.* Immediately afterwards, the Iron and Steel Division will hold its second Annual Luncheon and Business Meeting, and will hear a talk on *Recollections on Half a Century of Steelmaking* by J. L. Mauthe, chairman of the board, Youngstown Sheet and Tube Co. The Extractive Metallurgy Division's annual Stag Luncheon is scheduled for Wednesday noon, February 18th, with Granville S. Borden as the speaker. On Thursday, February 19th, the First Extractive Metallurgy Division Lecture will be presented by W. J. Kroll, consulting metallurgist, who will summarize *The Present State of Titanium Metallurgy.* The Annual Fellowship Dinner of The Metallurgical Society will be held on Tuesday evening, February 17th.

Excerpts from The Metallurgical Society Bylaws

Article VII

Section 9. The Nominating Committee shall consist of three members from each Division, selected by each of the Division Nominating Committees, one of whom shall be selected as Chairman by the President.

Article VIII

Section 1. The Nominating Committee of the Society shall select:

a. The nominee for Vice President (the President-Elect) of the Society, who automatically becomes a member of the AIME Board of Directors for a three-year term.

b. Every third year, the nominee for President-Elect of AIME, who automatically serves a three-year term on the AIME Board of Directors successively as President-Elect, President, and Past-President.

c. One nominee to serve as Director of AIME for a three-year term.

d. Nominees for Directors of AIME to fill unexpired terms on the Board of Directors should a Director from The Metallurgical Society be selected as President-Elect of AIME or as Vice President (President-Elect) of the Society.

e. The nominee for Treasurer of the Society.

The Nominating Committee shall designate two Society members on the AIME Board of Directors or nominees for the Board of Directors to serve as Vice Presidents of the Institute for one-year terms.

If a previously elected Vice President of the Society should become unavailable for the Presidency of the Society, the Nominating Committee shall also designate a nominee for President.

Section 2. The names and biographies of nominees shall be published in the July issue of the publication(s) of the Society. Any 25 members of the Society may submit additional nominations to the Society's Board of Directors for one or more of the positions specified in Article VIII, **Section 1.** Such nominations shall be submitted not later than August 15 of each year, and notice of the additional nominees for the position designated shall then be published in the October issue of the publication(s) of the Society.

Section 3. If additional nominations are not received by August 15, the President of the Society shall declare the Nominating Committee's nominees to be elected. If additional nominations are received, a letter ballot showing all nominees for the positions designated shall be sent on or about October 1 to all members of the Society in the United States, Canada, and Mexico. The ballots shall be returned within 30 days after they are mailed. The incumbent President shall appoint a Tally Committee to count the ballots, and the nominees receiving the plurality of ballots for each position shall then be declared by the Board of Directors to have been elected.

Section 4. Vacancies in any office of the Society occurring for any reason other than the expiration of term of election shall be filled by the President subject to approval by the Board of Directors.

Thirteenth Annual Off-The-Record Meeting In Pittsburgh Covers Many Topics

The Thirteenth Annual Off-the-Record Meeting, sponsored by the Pittsburgh Section, AIME, and the Engineers' Society of Western Pennsylvania, was held at the Penn-Sheraton Hotel, Pittsburgh, on November 7, 1958, with 856 registered members and guests attending. The meeting featured sessions on a diversity of subjects, with five simultaneous sessions both morning and afternoon sponsored by the following groups: Coal Division, Institute of Metals Group, and Mineral Industries Group (all part of the Pittsburgh Section AIME), the Pittsburgh Petroleum Subsection, and the Pittsburgh Section of the National Open Hearth Steel Committee.

Among the papers of particular interest to metallurgists given at the meeting were the following: Institute of Metals—*Origin of Textures*, by H. C. Stumpf, Aluminum Co. of America; *Use of Levitation Melting in Alloy Development*, by G. Comenentz and R. T. Begley, Westinghouse Electric Corp.; and *Fabrication of Columbium*, by H. M. McCullough, Refractomet Division, Universal-Cyclops Steel Corp.; National Open-Hearth Committee — *Performance and Properties of Desirable Charge Oxides* (in three parts: *Natural Oxides, Briquettes and Pellets*, and *Sinter*), by D. R. Bailey, Pittsburgh Steel Co., A. G. Dean, Crucible Steel Co. of America, and A. J. Parke, Jones & Laughlin Steel Corp., respectively; *Factors Controlling Iron Oxide Deposition in Open-Hearth Furnaces*, by J. H. Chesters, The United Steel Companies Ltd., Sheffield, England; *Progress Report on Basic Roof Performance*, by C. M. Burks, Weirton Steel Co.; and *Effect of High Firing Rates* (in three parts: *Operation, Refractories*, and *Maintenance*) by A. L. Gorman, Steel Co. of Canada Ltd., J. A. Cerroni, U. S. Steel Corp., and C. F. Smith, Jones & Laughlin Steel Corp., respectively.

Other interesting presentations included these items in the Mineral Industries Program: a film, *Iron Ore from the North*, presented by the M. A. Hanna Co.; a paper on *Rare Earth Alloy Steels*, by W. E. Knapp, American Metallurgical Products Co.; and a film, *Mining for Nickel*, presented by the International Nickel Co.

In addition to technical sessions, the meeting offered numerous opportunities for informal get-togethers, including a luncheon between morning and afternoon sessions, a suppliers' cocktail party, and the Fellowship Dinner, attended by more than 400 persons. Toastmaster for the dinner, which began at 7:00 pm, was J. M. Vonfeld, chairman of the Pittsburgh Section, AIME. Following dinner, Mr. Vonfeld presented the F. L. Toy Award to W. L. Kerlie and J. H. Richards, both of U. S. Steel Corp. for their paper entitled, *Origin and Elimination of Hydrogen in Basic Open-Hearth Steels*. The Toy Award is presented annually at the Off-the-Record Meeting by the Pittsburgh Section, NOHC—AIME in honor of F. L. Toy, a distinguished member of the section, and to encourage young men in the field to work for recognition. It is awarded for the best original contribution by a representative of Pittsburgh district plants on some subject related to facilities, practices, or products, and consists of a $100 savings bond together with an appropriate certificate.

Following presentation of the Toy Award, Leo F. Reinartz, Past President of AIME, talked briefly about the need for supporting the Building Fund Drive. He explained why the United Engineering Center is needed in addition to listing the reasons for its location, and urged those in the Pittsburgh area to support the drive.

Next to mount the rostrum was Augustus B. Kinzel, President of AIME. Dr. Kinzel was enthusiastic in his praise for the Pittsburgh meeting, pointing to it as an example of the continuing strength of AIME under the new organization.

To introduce the dinner speaker, Mr. Vonfeld called upon M. W. Lightner, vice president, U. S. Steel Corp. Mr. Lightner outlined the speaker's distinguished career before introducing Glenn B. Warren, vice president, Turbine division, General Electric Co. The topic of Mr. Warren's talk was *Our Standard of Living—Personal and Public*. Developing his subject historically, the speaker pointed out that the printing press had increased the spread with which knowledge could be developed and applied. With the industrial revolution, following the introduction of water and steam power, came engineering as a profession. Drawing examples from well-known situations, Mr. Warren showed how the standard of living of American society has failed to keep up with the rapid gains in the standard of living of the average individual American. He said that we must realize the full potentials of the engineering age, and eliminate present impediments to full production. Mr. Warren called for greater efforts to improve our public standard of living, as represented by such things as our educational system, urban redevelopment, and the national highway system. He stressed the fact that such efforts are just as important, if not more so, that those aimed at raising our personal standard of living.

Mr. Warren's talk was a well received climax to the Thirteenth Annual Off-the-Record Meeting in Pittsburgh.

Among those whose efforts contributed to the successful meeting were: general chairmen F. M. Richmond and J. N. Albaugh, general vice chairman R. H. Shrut; Pittsburgh Section AIME Officers: chairman, J. M. Vonfeld; vice chairman, J. H. Henderson; secretary, R. S. Crowell; treasurer, J. H. Melvin; Pittsburgh Section NOHC Officers: chairman, R. N. Barnhart; vice chair-

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G. F. SULLIVAN

Symposium to hear Editor of "The Iron Age"

George F. Sullivan, Editor of THE IRON AGE, will be the luncheon speaker at the **Mechanical Working Committee Symposium** to be held at the Del Prado Hotel, Chicago, on Jan 21, 1959. Mr. Sullivan will speak on *An Insider's Look at the Russian Steel Industry*.

This one-day symposium will include papers on *Factors Affecting Shape and Surface Texture of Hot and Cold Rolled Products* in the morning and on *Continuous Heat Treatment of Flat Rolled Products* in the afternoon. The registration fee of $12.50 will include lunch and a copy of the proceedings. Advance registration should be sent directly to *Phillip H. Smith, La Salle Steel Co., P. O. Box 6800A, Chicago 80, Ill.* The complete program was given on page 818 of the December issue of JOURNAL OF METALS.

AIME

BOARD OF DIRECTORS

Recent actions taken by the Institute Board of Directors.

► The Metallurgical Society of AIME announced that the Institute of Metals Division Lecturer in February 1959 will be Professor Frederick Seitz, department of physics, University of Illinois.

► The Metallurgical Society announced that the IMD Lecturer for 1960 will be N. F. Mott of Cambridge University, England. In even-numbered years a foreign lecturer is invited.

► The citation in honor of the Jackling Lecturer Ralph S. Archibald has been approved as follows: "A successful career in mining geology, consulting work and operation of substantial iron ore properties, and for his lecture, 'Economic History of the Lake Superior Iron District.'"

► The suggested change in the Institute's Bylaws and Rules, as previously published in the August issue, was approved, so that hereafter the term "Entrance Fee" will replace "Admission Fee" in all instances.

► Robert M. Mahoney, AIME's representative of the EJC Air Pollution Committee, was appointed as AIME delegate at the U. S. Public Health Service Conference on Air Pollution to be held Nov. 18 to 20, 1958, in Washington, D. C.

► Professor H. U. Ross, Department of metallurgical engineering, University of Toronto, was the winner of the Journal of Metals Award for 1958. His paper is entitled *Smelting of Titaniferous Ores*. The award was presented in April 1958.

► The Metallurgical Society announced that the F. B. McKune Award for 1958 was presented to

(Continued on page 55)

Exxplosive Shock Paper

Mr. Cyril Stanley Smith, professor of metallurgy and former Director of the Institute for the Study of Metals, University of Chicago, has published a paper in the October issue of TRANSACTIONS of The Metallurgical Society of AIME. The paper, *Metallographic Studies of Metals After Explosive Shock*, gives added emphasis to the increasing importance of explosive forming. The forward emphasizes that "metallography promises to be a useful tool in studies of shock hydrodynamics . . "

Call For Semiconductor Papers

The Semiconductors Committee of the IMD which, with the Boston Section, AIME, will sponsor a conference on *Properties of Elemental and Compound Semiconductors*, has issued a call for papers to be given during two sessions of the meeting, to be held at the Statler Hotel in Boston, August 31st to September 2nd, 1959. The 3-day conference will also feature two sessions of invited papers and a tour of Massachusetts Institute of Technology Lincoln Laboratories, as well as ample opportunity for informal discussion and fellowship.

Prospective authors are requested to submit proposed titles of papers on or before Feb 1, 1959 and abstracts of up to 150 words in triplicate by March 1, 1959. All material should be sent to *W. C. Hittinger, Bell Telephone Laboratories, 555 Union Boulevard, Allentown, Pa.*

Fall Meeting of NOHC Eastern Section Held

About 250 registrants participated in the Fall Meeting of the Eastern Section of the National Open Hearth Steel Committee in Philadelphia, Friday, October 10th, at the Warwick Hotel in Philadelphia.

The first order of business in the morning session, following the opening remarks by Section Chairman G. S. Baldwin, Standard Steel Works div., Baldwin-Lima Hamilton Corp., Burnham, Pa., was the presentation of the awards for the prize paper contest run by the section. The first prize of $100 went to Fred A. Leslie, Jr., Bethlehem Steel Co., Sparrows Point, Md., for his paper on *Air Infiltration Into Fuel-fired Equipment*. Mr. Leslie presented his paper before the group. William Sabolchy's paper on *Mold Scrapping Program at John A. Roeblings & Sons Corp.* took the second prize of $50.

The major part of the morning session was devoted to the regular technical program, which took the form of a panel discussion moderated by Henry Tear, Washburn Wire Co., Phillipsdale, R. I. The members of the panel each presented short papers, as follows: J. B. Kopec, Colorado Fuel and Iron Corp., Roebling, N. J., *Recarburization of the Open Hearth Bath;* A. V. Leun, Bethlehem Steel Co., Bethlehem, Pa., *Some Applications of Guniting in the Open Hearth Department;* J. Madden, Colorado Fuel and Iron Corp., Claymont, Del., *Open Hearth Waste Heat Boilers;* Paul Morrow, U. S. Steel Corp., Fairless Works, *Use of Steel Roof Centers at Fairless Works;* and H. W. Potter, Lukens Steel Corp., Coatesville, Pa., *Improved Mill Yield Through Better Mold Design*.

Mr. Kopec's paper described attempts to raise carbon levels by injecting graphite flakes or powder into melts with compressed air and summarized the results obtained in both cases. The applications of guniting in the open hearth department at Bethlehem Steel Co., as described by A. V. Leun, are many and varied, taking advantage of the versatility of this method to effect both repairs and regular maintenance. The brief summary of waste heat boiler operation at Claymont, Del., presented by Mr. Madden, directed attention of the group to an oft-neglected phase of open hearth operation. In his talk on the use of steel roof centers at Fairless Works, Paul Morrow indicated how this innovation had facilitated open hearth rebuilds. Finally, H. W. Potter showed how a slight change in slab mold design had resulted in a considerably increased yield from the plate mill. Considerable discussion in each case, ably moderated by Henry Tear, caused the morning session to run slightly behind schedule.

Following lunch, however, the afternoon session started promptly at 1:15 p.m. under the direction of co-chairmen C. B. Jenni, General Steel Castings Corp., Eddystone, Pa., and J. C. MacNeill, Bethlehem Steel Corp., Bethlehem, Pa. The first speaker on the afternoon agenda was M. F. Yarotsky, U. S. Steel Corp., South Works, who presented the *Latest Report on Russian Steelmaking*. Although much of this talk took the form of a well illustrated travelogue based on Mr. Yarotsky's recent trip to Russia, sufficient time near the end of his presentation was allotted to a comparison of the United States and the USSR with regard not only to steelmaking progress, but also to general economic status of the two powers. The second speaker of the afternoon was W. S. Debenham, U. S. Steel Corp., Pittsburgh, Pa., who talked on the *Quality and Development of Modern Open Hearth Refractories*. Mr. Debenham was emphatic in his approval of the trend toward standardization and more scientific evaluation of refractories. He said these developments, furthered by users and suppliers alike, were bringing order out of what had been chaos in the field of refractories and their applications. To close the afternoon

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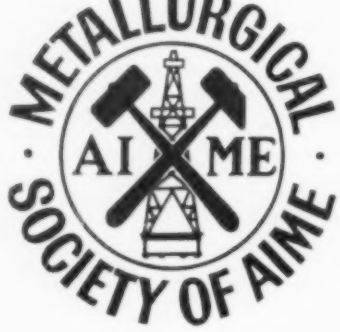
NEW MEMBERS by the THOUSANDS



- To maintain its effectiveness, your Metallurgical Society must continue to include the great majority of the professional metals men in its membership. This means gaining new members by the thousands to keep pace with the growth of the profession.
- The 1959 goal of 1,500 new members will, when achieved, result in greater benefits and more services to all members. This substantial growth in membership will result from every member acknowledging his responsibility for taking a personal part in the concerted drive which is now underway.
- Metallurgical Society staff members, along with local section membership chairmen, stand ready to help members gain new members. Up-to-date application forms and descriptive material are available from both sources. Help yourself to a better professional society —sign up a new member this month!

Please Use Handy Form Below

The Metallurgical Society of AIME, 29 W. 39th St., New York 18, New York

Gentlemen:

Count me in on the membership drive. Please help me to get new members by doing the following:

____ Send new application forms and brochures

____ Invite Mr. _____

to join AIME at my suggestion. His address is

_____

My name is: _____

Address: _____

AROUND THE SECTIONS

Direct Reduction of Iron Ore, Topic at N. Y. Section Meeting

Dr. Bruce S. Old, vice president, Arthur D. Little Inc., Cambridge, Mass., was the speaker at the October meeting, **New York Section,** AIME, on October 23rd.

Talking on the subject *Direct Reduction of Iron Ore*, Dr. Old stated that no direct reduction process has ever been used commercially in the United States. In the last decade there has been a reversal of the previous conclusion that direct production is impractical. The rising cost of scrap, adverse effect of fine ores on blast furnace practice, the increasing use of lower grade ores, and the rapid rise in the cost of new capital equipment, were some of the economic reasons for this reversal.

Dr. Old briefly described five direct reduction processes being considered by US interests: the R-N process, the Madaras process, H-Iron process, Nu-Iron process, and the Esso Research-Little process.

"The big problem," Dr. Old pointed out, "is to present an accurate operating cost figure. Estimates on cost above ore can range between about $10 and $20 per ton of product in briquetted form. These estimates certainly put direct reduced ore in the area of serious competition with other iron unit charge materials for blast furnaces and steelmaking. Thus, it can be predicted with some confidence that direct reduction processes will be utilized in certain areas in the not-too-distant future."

AIME President Addresses N. Y. Section

A favorable prognosis of the newer and special property metals was given by Augustus B. Kinzel, President of the AIME, in his talk before the N. Y. Section, AIME, on December 3rd. Answering a question about the future of such metals as beryllium, lithium, and tantalum, the AIME President said that much depended upon the properties of the individual metals.

Setting a premise that it takes time to learn the use of metals, Dr. Kinzel indicated that columbium and tantalum have good prospects. Beryllium "is one of those things." It could be used as a moderator in atomic piles, but there are many other competing materials.

Lithium is in a peculiar position, he stated. More research is needed, but it is potentially a major alloying element. A renaissance in tungsten as the most useful future high-temperature alloy is possible.

Special emphasis was placed on the need for fundamental research by Dr. Kinzel. "Research," he said, "has become organized particularly in the last 10 years. People look on it in a different light. It is an integral part of a business and has to be so regarded."

Citing the relative percentages of sales dollars spent on research and development for different industries, the speaker placed the metals industry percentage at about 1.0 pct, below that of the aircraft, pharmaceutical, electrical, and chemical industries.

Commenting that his statements were of a personal nature and did

(Continued on page 55)

The Powder Metallurgy Group of the **New York Section** met at the Brass Rail Restaurant, New York City, on November 12th, to hear a talk by Dennis K. Pickens, president of Chemetals Corp., on *A New Challenge to Pyrometallurgy and the Metals Industry*. Under discussion were the chemical precipitation and direct rolling of powders and its adaptation to commercial copper strip. Also described was a new technique of producing ferrous and nonferrous co-precipitated powders. Chemetals Corp. is associated with E. W. Bliss Co., Sherritt-Gordon Mines, Ltd., and Fluor Corp., Ltd. Kempton Roll served as chairman of this meeting.

The Physical Metallurgy Group of the **New York Section** will hold its second meeting of the 1958 to 59 year on January 21st., at the Polytechnic Institute of Brooklyn, N. Y. B. D. Cullity, University of Notre Dame, will be the featured speaker. He will discuss *Torsional Deformation*. The program includes a laboratory visit at 2:30 p.m., dinner at 6:30 p.m., and the lecture at 7:30 p.m.

Members of the **Pittsburgh Section** were treated to a program on the Russian iron and steel industry at a dinner-meeting sponsored by the Section's Mineral Industry Group on Oct. 8, 1958. The guest speakers, J. B. Austin, U. S. Steel Corp.; N. B. Melcher, U. S. Bureau of Mines; and G. Mohling, Allegheny Ludlum Steel Corp., were members of a 19-man delegation which had recently made an extensive tour of the Russian iron and steel industry. The illustrated talks were presented in the form of a panel discussion.

The Increasing Importance of Special Metals to Electronics was the featured topic at the November 14th meeting of the **St. Louis Section,** held at the Hotel York, St. Louis. Guest speaker, Edward Orban, manager of inorganic product development, research and engineering div., Monsanto Chemical Co., discussed the metallurgy and uses of the lesser known metals and alloys.

The **El Paso Section** held a joint dinner-meeting with American Institute of Electrical Engineers on November 12th., in the Hotel Cortez, El Paso. Edward Beck, engineer, Westinghouse Electric Corp., East Pittsburgh works, was the after-dinner speaker. He presented a travelog on his experiences in Russia during an engineering meeting held there two years ago.

The **Reno Subsection** met for cocktails and dinner on November 15th., at the Big Meadow Hotel, Lovelock, Nev. A highlight of this event was an afternoon tour of Eagle Pitcher's Colado diatomaceous earth plant, east of Lovelock. At the dinner, F. J. Mecham, president and general manager, Sierra Engineering Co., was a featured speaker. He discussed iron ore beneficiating equipment in the Buena Vista mining district, Pershing County. Subsequently J. E. Fennell, development engineer for Eagle Pitcher Co., exhibited photomicrographs of diatomaceous earth. Also on the bill for the evening, was Keith Papke, geologist, exploration dept., Southern Pacific Co., who spoke on the mineral potential and geologic exploration in the Lovelock area.

The Hotel Traylor, Allentown, Pa., was the scene of the October 24th., dinner-meeting of the **Lehigh Valley Section.** The speaker of the evening was John S. Nielsen, chairman of the department of metallurgical engineering, New York University. His topic for the night was *Soviet Metallurgy*.

On December 5th., the Section held Ladies Night, at the Lehigh Valley Club, Allentown, Pa. The guest speaker at this social event was Augustus B. Kinzel, AIME President. Dr. Kinzel spoke on *Research From Rocks to Radar*.

The **Morenci Subsection** held a meeting at the Longfellow Inn, Morenci, Ariz., on October 28th. Ralph Johnson, Western Knapp Engineering Co., was the featured speaker. In his talk, Mr. Johnson described the improvements in the smelter design and the construction of the new Kennecott Copper Corp.'s smelter at Hayden, Ariz. (See Reporter.)

R. S. BUSK

Dow Award Bestowed to Dr. R. S. Busk

Dr. Robert S. Busk was recently awarded the *1958 William H. Dow Memorial Award* for research in the field of magnesium.

The award was presented to Dr. Busk in "recognition of his outstanding leadership and invention in the field of pellet metallurgy, specifically for magnesium-alloy extrusions."

Established in 1949, in memory of the company's late president and son of its founder, the award is given annually to a member or members of the magnesium products department of Dow Chemical Co.

Dr. Busk is head of the metallurgical department of the company, a position he has held since 1956.

Conference and Show Featured at Plant Engineering Program

The Plant Maintenance and Engineering Conference program will take place in Cleveland, January 26 to 28, and will include a plant maintenance & engineering show from January 26 to 29 inclusive.

A broad revision of topics will be the feature of the conference with ten round-table sessions devoted to the special problems of individual industries. Other sessions will be devoted to nuclear industry, assembly plants, and the abrasive products industry.

Also included are discussions on *Arc Welding in Maintenance, Maintenance in Metal-Working and Metal-Fabricating Plants, Maintenance in Nuclear Plants,* and *Maintenance in Foundries.*

Recent EJC News

1958 Surveys The EJC (Engineering Joint Council) is now completing a study of engineering salaries, with the final report more comprehensive than the 1956 survey, and containing over 650 organizations. It will contain data on twenty industrial activities on various levels of government and engineering education. Also included will be special tables presenting data for engineers holding Masters and Doctorate degrees.

Advance orders for publication are now being accepted. Contact: *EJC, 29 West 39 Street, New York 18, New York;* Price $3.00.

Demand For Engineers The annual study by the EJC on *Demand for Engineers* is near completion. The report will appraise current industrial and governmental needs for engineers, and will contain other significant data on engineering employment from organizations employing over 200,000 engineers.

EJC-ECPD A joint committee was established in order to promote greater affiliation between EJC and ECPD by the Board of Directors. The committee will review plans for an amalgamation and consolidation of the two.

New EJC Member The South Carolina Society of Engineers was accepted as an affiliate member by the Board in September. Total membership for EJC is now 20.

Stress Corrosion Conference Session

The program published in the December JOURNAL OF METALS for the Conference on Stress Corrosion Fracture, to be held in Pittsburgh at Mellon Institute on April 2nd and 3rd, inadvertently omitted a session on *Physical Metallurgical Aspects of Stress Corrosion.* This will be given at 9 am on April 3rd. The complete program for this session follows:

9:00 am

Session III-Physical Metallurgical Aspects of Stress Corrosion

Chairman:
F. L. LaQue, Development and Research div., International Nickel Co.

Stress Corrosion Cracking of Single Crystals of Stainless Steel: H. W. Paxton, Metals Research Laboratory, Carnegie Institute of Technology.

Electrochemical Aspects of Stress Corrosion: H. J. Engell, Max Planck Institut für Eisenforschung, Düsseldorf, Germany.

Dependence of Stress Corrosion Cracking Susceptibility on Age-Hardening in a Copper-Nickel-Silicon Alloy: W. D. Robertson, Department of Metallurgy, Yale University; E. G. Grenier, W. H. Davenport, and V. F. Nole, Research Laboratory, Chase Brass and Copper Co. Inc.

Mechanisms of Stress Corrosion of Stainless Steels and Other Materials by High Temperature Chloride Waters and by Hot Salts: M. G. Fontana, Department of Metallurgy, Ohio State University.

Physical Metallurgy of Stress Corrosion Fracture: P. G. Bastien, Societe des Forges et Ateliers du Creusot, Paris.

The session listed as Session III in the December article will be given at 2:30 pm on April 3rd rather than 9 am. It will also include a paper on *Stress Corrosion Cracking in Low-Carbon Steel,* by H. L. Logan, metallurgy div., National Bureau of Standards.

Inquiries regarding pre-registration should be directed promptly to the Chairman of the Arrangements Committee, *Professor William R. Bitler, Department of Metallurgical Engineering, Carnegie Institute of Technology, Pittsburgh 13, Pa.*

NOHC Fall Meeting

(Continued from page 51)

technical session, F. E. Bird, Jr., Lukens Steel Co., Coatesville, Pa., described *New Approaches to Head and Eye Injury Prevention in Open Hearth Operations.* Mr. Bird told how a carefully thought-out and implemented safety program is being effected at Lukens Steel Co. with considerable success.

Many of those present during the technical sessions remained to take part in the social programs which are an integral part of Open Hearth meetings. Following a reception, the annual Fellowship Dinner was held, starting at 7:00 p.m. The featured speaker of the evening was Leo F. Reinartz, Armco Steel Corp., Middletown, Ohio, who delivered an abbreviated version of his extensive paper describing *100 Years of Progress in Basic Open Hearth Steelmaking.*

Among those responsible for arranging the meeting were G. S. Baldwin, Chairman, Eastern Section, G. M. Hagenberger, Secretary-Treasurer of the Section, Standard Steel Works div., Baldwin-Lima Hamilton Corp., Burnham, Pa., and members of the suppliers' committee: Chairman J. W. Corriston of E. J. Lavino and Co., Vice Chairman C. L. Corson, G. and W. H. Corson, Inc., L. U. Park of Park and Williams Co., J. J. Edmiston of U. S. Graphite Co., A. E. Bickele of General Refractories Co., R. F. Babcock of Linde Co., div. of Union Carbide Corp., and H. Kenworthy of R. L. Batteiger Co.

WAAIME Scholarships

Scholarship activities of the past five years have been reported by the Woman's Auxiliary to the AIME. The WAAIME Educational Fund has given excellent support to the Institute in this field of scholarships.

Local scholarships granted by the WAAIME Sections show an impressive record. The Arizona-Tucson Section has awarded 12 scholarships

for a total of $3000. The California-Northern Section granted $500 during the last five years, plus $1000 awarded last year. Colorado-Denver Section has given $3990 in scholarships, plus $365 last year. Colorado San Juan Section gave four scholarships totaling $325, and one last year for $105. The Illinois-Chicago Section has awarded one scholarship for $750. The Missouri-St. Louis Section has given four scholarships totaling $800. The New York City Section has given in scholarships an aggregate of $4465, including $900 divided among three awards last year.

The Peru-Lima Section awarded nine scholarships for approximately $1560 during the last five years, exclusive of last year's four awards totaling about $240. Pennsylvania-Pittsburgh Section donated $2800 in 11 scholarships, and one $1000 award last year. Texas-El Paso Section gave five scholarships that totaled $850, plus three last year totaling $725. Utah-Salt Lake City Section gave eight scholarships over the years for a total of $2000.

The Cleveland Section reports that, in addition to three scholarship loans, for $300, $110, and $350, they have contributed to the Cuyahoga County Nursing Home and the Inner City Parish. These excellent local projects are a sample of WAAIME's fine work.

Pittsburgh Meeting

(Continued from page 50)

man, E. E. McGinley; secretary, E. B. Snyder; treasurer, J. H. Smith; past chairman, D. L. McBride; Suppliers' Committee: H. R. Loxterman, chairman, P. A. Gaebe, E. B. Shaw, Robert Wright, N. F. Tisdale, Jr., T. A. Hayden, and E. T. McKeon; and chairman of presentation, J. G. Bassett.

Nuclear Fuels Brochure

Sylvania-Corning Nuclear Corp. has announced a new 24-page brochure titled *Nuclear Fuels: Key to Reactor Performance.*

Divided into three principal sections, the book contains an introductory section on the *Aspects of Reactor Design*, a section on details of reactor fuels, including solid fuel element's composition and design, and a third section on typical reactors and their fuels, including those termed *historically significant reactors*, as well as some recently built reactors.

Printed in two colors and fully illustrated with photographs and detailed line sketches, it may be obtained by writing the *Sylvania-Corning Nuclear Corp., Bayside. N. Y.*

N. Y. Meeting

(Continued from page 53)

not necessarily reflect the views of Union Carbide Corp., of which he is a vice president, Dr. Kinzel inferred a relationship between research and growth in any particular industry. Titanium, columbium, tantalum, germanium, and selenium have developed into useful metals because of extensive research. "You've got to think broadly and not let a decade stand in your way," he declared. Fundamental research should account for between 30 and 40 pct of total research. Given time —in some cases as much as 15 to 20 years—plus *serendipity*, or luck, it will pay off in the long run.

Dr. Kinzel concluded his talk with a review of AIME activities and a recap of the efforts to unite the professional engineering societies.

Board of Directors

(Continued from page 51)

R. W. Joseph and L. J. Trilli for the paper *A Study of Wall Erosion in Wide Slab Molds.*

► The Metallurgy Society announced that the Open Hearth Conference Award for 1958 was presented to R. E. Stoll and E. C. Rudolphy for the paper *Effect of Nozzle Characteristics on Steel Pouring Streams.*

► The Society of Petroleum Engineers of AIME has a 30-min sound film strip on student guidance at the high school level. Preparations are being made for the other two Societies to print such a film strip if possible.

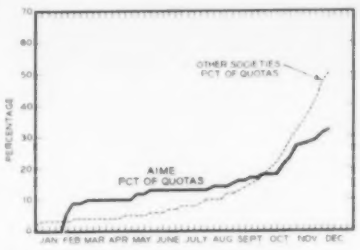
► The formation of the Golden Gate Petroleum Subsection of the San Francisco Section was approved.

► Augustus B. Kinzel announced that the Hal Williams Hardinge Award Committee had selected Dr. Oliver Bowles posthumously as the first recipient.

► Clark L. Wilson, Chairman of the Saunders Gold Medal Committee, announced that the recipient of the award in 1959 will be John B. Knaebel. The citation in his honor reads: "For his versatility and courageous leadership in pioneering, exploring, developing and managing highly successful mining ventures as a leader among men—yet one of them."

► F. R. Jones, mine superintendent, MacIntyre Development, Titanium Div., National Lead Co., has been selected as the recipient of the

(Continued on page 56)



Building Fund Drive Shows Strong Support

The United Engineering trustees have announced that as of December 16th, 274 pledged contributions from industry total $3,818,708 toward the United Engineering Center Building Fund. The mining, metallurgical, and petroleum industries are particularly well represented.

In addition to the results obtained by Louis S. Cates and H. De Witt Smith in the nonferrous mining and metallurgical industries—mentioned in previous issues—JOURNAL OF METALS readers will be interested to read that the activity of Leo F. Reinartz and his associates measurably aided the pledging of approximately half a million dollars from the steel industry.

Reports from AIME sections indicate constant attention being given to the building fund drive.

The **Utah** section was the first to reach its goal. On December 16th, records at AIME headquarters showed that 100 Section members had pledged $8955—109 pct of the goal allocated to the Section. Many members of this Section have not yet been approached. The excellent results stem from the organization of the campaign directed by Norman Weiss, and reflect the enthusiasm of his co-workers.

Two petroleum sections that have exceeded their goals are the **Gulf Coast** section ($25,190 from 785 members) and the **New York** section ($8165 from 30 members). The **Tri-State** section, with only 76 members, reached its goal early in December.

Other Sections are active: telegraph reports indicate that the **Pennsylvania Anthracite, Uranium,** and **Montana** sections have met their targets; **St. Louis, Ohio Valley,** and **Colorado Plateau** are well on their way.

In spite of these excellent reports, the AIME as a whole, with 34 pct of its $500,000 membership quota obtained at mid-December, was lagging behind all but one of the other societies in percentage of quota attained. Many AIME members have not yet been approached, but everyone will have a chance to help build the new home of the engineering professions before the campaign closes.

Board of Directors

(Continued from page 55)

Peele Award in February 1959 for his paper *More Rock Per Dollar from The MacIntyre Pit*, Mining Engineering, April 1956.

► The following resolution was unanimously voted (at the September 19 meeting): Resolved, that the Board of Directors of the American Institute of Mining, Metallurgical, and Petroleum Engineers unanimously agrees that the Utah Local Section has done an outstanding job in its arrangements for this meeting.

Further, the Board wishes to express its thanks and appreciation for the successful outcome of the efforts involved.

OBITUARIES

Merton W. Sage (Member 1923) died at his Bronxville home on Nov. 11, 1958. Mr. Sage, a patent attorney and partner in the law firm of Pennie, Edmonds, Morton, Barrows & Taylor, graduated from Massachusetts Institute of Technology with a degree in engineering in 1907. After graduation he entered the Georgetown University School of Law and worked with Sage Bros. Co. for one and one half years, and for the U. S. Patent Office as an assistant examiner handling applications for patents in the field of metallurgy for another two and a half years. He then joined the patent department of the General Electric Co. at Schenectady N. Y. and was on the staff there for six years. In 1917, Mr. Sage entered the law firm of Pennie, Davis, Marvin & Edmonds, as a specialist in metallurgical affairs. At the time of his death Mr. Sage resided in Bronxville, New York.

Roger L. Strobel (Member 1918) died in Portland, Ore. at the age of 75. He was a former superintendent of Asarco's East Helena, Mont. plant and was associated with Linde Air Products of Salt Lake City.

John S. Stewart (Member 1916) passed away in New York City on Oct. 14, 1958 after a brief illness. A graduate of the University of Missouri School of Mines, he started his career with the American Smelting and Refining Co. in Omaha, Neb., then moved on to the Russia Asiatic Ltd., in Siberia, Russia. From there he went to work for the Kingdom Mining & Smelting Co. at Galetta, Ont; he later joined the Union Miniere du Haut in Katanga, Belgian Congo. While working at Trepeca Mines Ltd., London, as a consulting metallurgical engineer, he helped in the design and operation of a scotch hearth smelter and lead refinery in Zvecan, Yugoslavia. In 1948 he developed an improved blast furnace known as the Stewart Inverted-bosh Furnace. At the time of his death, Mr. Stewart was 69 years old.

MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME membership on Nov. 1, 1958 was 30,815; in addition 3,279 Student members were enrolled.

ADMISSIONS COMMITTEE

J. H. Scaf, Chairman; Alfred Bornemann; F. B. Foley; T. D. Jones; L. L. Seigle; J. M. Warde; H. K. Work.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Vernon E. Anderson, Chicago, Ill.
Lloyd E. Bebler, Hammond, Ind.
Borje E. Bergsman, Vasteras, Swed.
William A. Black, Cleveland, Ohio
Bernard S. Borie, Oak Ridge, Tenn.
Robert E. Burket, Brackenridge, Pa.
Robertson F. Compbell, Monroeville, Pa.
Fred M. Charles, Portland, Ore.
John H. Coobs, Oak Ridge, Tenn.
Georges Delaunay, Paris, France
Frazier M. Douglass, Birmingham, Ala.
Gladys E. Dunkle, Washington, D. C.
Harry A. Durney, Jr., Bedford, Ohio
Donald W. Evans, Montreal, Can.
Irving D. Feinland, Belle Harbor, N. Y.
Frank M. Fisher, Chicago Hts., Ill.
William J. Fulton, Keokuk, Iowa
Michael J. Hughes, Jr., Seattle, Wash.
George O. Johnstone, Houston, Texas
Enos L. Key, Mexico, Mo.
Ralph C. Kirby, College Park, Md.
William C. Kollmann, Industry, Pa.
Daniel E. Krause, Columbus, Ohio
Richard H. Lambert, Pittsburgh, Pa.
Achille G. Lefebvre, Brussels, Bel.
Kenneth C. Lowstetter, Hartford, Conn.
Samuel J. Manganello, Monroeville, Pa.
James E. Minor, Richland, Wash.
John S. Rinehard, Golden, Col.
Felix A. Schaufelberger, Basel, Switzerland
James A. Shea, Gary, Ind.
Emlyn N. Smith, Latrobe, Pa.
George D. Storm, Colonia, N. J.
Carl P. Stroble, Tarentum, Pa.
Max J. Trzeciak, Columbus, Ohio
Joseph H. Tuck, Port Colborne, Can.
H. Austin Tucker, Washington, D. C.
Thomas L. Van Zandt, Seattle, Wash.
Walter L. Vaughan, Chicago, Ill.
Robert C. Weir, Clarkson, Can.

Associate Members

Victor Besso, New York, N. Y.
Todd L. Kolb, Detroit, Mich.
Bruce D. Orr, Pittsburgh, Pa.
Michael Savitske, Youngstown, Ohio
Griffith E. Thomas, Niles, Ohio

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Charles W. Allen, Notre Dame, Ind.
Brian S. Berry, Yorktown Heights, N. Y.
George Carlbert, Monacat, Pa.
Irving Clock, East Chicago, Ind.
James L. Golding, Valparaiso, Ind.
Lloyd A. Heldt, Philadelphia, Pa.
Carter R. Kelly, Seattle, Wash.
Louis W. Lherbier, Cuddy, Pa.
Norman R. Lindblad, Chicago, Ill.
Lawrence A. Neimark, Lemont, Ill.
Harold M. Priestly, Pittsburgh, Pa.
Raymond C. Stoll, Chicago Heights, Ill.
John R. Wynnyckyj, Copper Cliff, Can.

REINSTATEMENT MEMBER

Charles D. Preusch, Harrison, N. J.

REINSTATEMENT—CHANGE OF STATUS

Junior to Member

Paul D. Gorsuch, Scotia, N. Y.
Edward A. Kachik, Wilmington, Del.

CHANGE OF STATUS

Student to Member

Robert Y. Scapple, Los Angeles, Calif.

Associate to Member

John P. McCune, Chicago, Ill.

Junior to Member

Jean F. Petit, S.erO., France

Special Reinstatement

W. D. Carleton, Ann Arbor, Mich.

NECROLOGY

Date Elected	Name	Date of Death
1940	Mason L. Bingham	Sept. 4, 1958
1930	George H. Corey	Nov. 11, 1958
1928	G. P. Crutchfield	June 10, 1958
1953	E. D. Flournoy	Unknown
1925	Laurence F. Hearne	1956
1936	H. W. Hentschel	Oct. 20, 1958
1942	W. D. Hubler	Sept. 20, 1958
1943	J. E. Jewell	July 9, 1958
1952	Fred T. Mathews	Unknown
1923	Merton W. Sage	Nov. 11, 1958
1916	John S. Stewart	Oct. 14, 1958
	Roger L. Strobel	Unknown

PROFESSIONAL SERVICES

MAX STERN
Consulting Engineer
Expert for Scrap Recovery and Shipwrecking—Modernization of Plants and Yards for Ferrous and Nonferrous Metal Scrap
10 East 40th St. New York 16, N. Y.

DR. E. TSUTSUMI
Registered Japanese Patent Attorney & Consulting Engineer
PATENT MATTERS handled . . . TECHNICAL TEXT translated from Japanese into English or vice versa: 2¢ an English word.
Central P.O. Box 1545 Tokyo, Japan

H. L. TALBOT
Consulting Metallurgical Engineer
Extraction and Refining of Base Metals
Specializing in Cobalt and Copper
Room 911, 209 Washington St. Boston 8, Mass.

EDWARD G. VOGT
Consulting Chemical-Metallurgical Engineer
Applied Statistics
Experimental Designs Data Analysis
1130 Woodlawn Street, Bethel Park, Pa.
Telephone: TEnnyson 5-5241 (Pittsburgh)

Annual Meeting — Technical Program

The Metallurgical Society of AIME

February 15 to 19, 1959, St. Francis Hotel, Sheraton-Palace Hotel, San Francisco

SUNDAY, FEBRUARY 15, PM

Met. Soc.
Current Issues in Metallurgical Education

(Arranged by the Committee on the Metallurgical Profession and the Education Committee of The Metallurgical Society)

2:00 pm — St. Francis Hotel — Italian Room

J. E. Dorn, Chairman

Orthodoxy, Heterodoxy, and Metallurgical Education: *R. F. Mehl*, Carnegie Institute of Technology.

The Future of Process Metallurgy: *T. B. King*, Massachusetts Institute of Technology.

Education in Materials Engineering: *R. A. Flinn*, University of Michigan.

Council of Education
Social Hour

5:00 pm — Sheraton Palace Hotel — Rose Room

Council of Education
Buffet Dinner

6:00 pm — Sheraton Palace Hotel — Rose Room

Council of Education
Technical Session

8:00 pm — Sheraton Palace Hotel — Concert Room

Speaker: *Edward Teller*, University of California.

Subject: *Peaceful Uses of Nuclear Explosives.*

TUESDAY, FEBRUARY 17

Met Soc — Social Hour

6:00 pm — St. Francis Hotel — Colonial Room
(Cocktails available)

Met Soc — Annual Dinner

7:00 pm — St. Francis Hotel — Colonial Room

W. R. Hibbard, Jr., President, *Presiding*

Speaker: Robley C. Williams, Assistant Director, Virus Research Laboratory, University of California.

Subject: *Structural Studies of Viruses.*

MONDAY, FEBRUARY 16, AM

IMD
Symposium on Interfaces and Surfaces

9:30 am — St. Francis Hotel — California Room

G. M. Pound, Chairman

Thermal Grooving of Grain Boundaries: *W. W. Mullins and P. Shewmon*, Westinghouse Electric Corp.

Grain Boundary Energies of Metals: *N. Gjostein*, Thompson Ramo Wooldridge, Inc., and *F. N. Rhines*, Carnegie Institute of Technology.

Impurity and Surface Effects on Grain Boundary Migration: *C. G. Dunn and K. T. Aust*, General Electric Co.

MONDAY, FEBRUARY 16, AM

IMD

Research Summaries on Interfaces and Surfaces (I)

(Based on Submission of Research Abstracts)

9:30 am St. Francis Hotel Borgia Room

R. R. Hultgren, Chairman

Yield Phenomena in Magnesium Single Crystals Containing Nitrogen: *Doyle Geiselman*, Electro Metallurgical Co., Div. of Union Carbide Corp., and *A. G. Guy*, Purdue University.

Single crystals were grown from high-purity magnesium containing known amounts of nitrogen in the range 0.0008 to 0.0048 wt pct N. Crystals of known orientation were tested in tension in an Instron machine to determine the yield strength and to observe whether a yield point occurred. The strength of the slowly-cooled crystals remained constant over the entire range of nitrogen content while the strength of the solution-treated and quenched crystals increased with an increase in nitrogen content. Slowly-cooled crystals or those given a solution heat treatment did not show a yield point. However, crystals that were aged following a solution treatment showed a yield point for all of the nitrogen contents studied. The yield point disappeared with further aging and straining, but more rapidly than with just aging for a comparable period. It was concluded that nitrogen caused the yield point by the Cottrell mechanism.

The maximum solid solubility of nitrogen in equilibrium with magnesium nitride was estimated to be 0.0048 wt pct.

Cyclic Straining and Fatigue of Metals: *L. F. Coffin, Jr.* and *J. Tavernelli*, General Electric Co.

The resistance of metals used in engineering structures to deformation and fracture under conditions of unidirectional loading has been studied in detail for many years. The mechanical resistance of metals to cyclic loading is equally important, but the attention given to this problem is nowhere as great. In particular, there is little information available for the behavior of metals where the level of reversed cyclic stress is large, such that cyclic plastic strains of some magnitude are produced. This is of particular importance in the case of thermal stress fatigue where failure can occur as a consequence of comparatively few cycles of thermally induced mechanical deformation. There are numerous applications in the mechanical working of metals where the knowledge of cyclic strain behavior is also important.

The deformation and fracture characteristics of eight metals subjected to fully reversed cyclic strain has been investigated. It is found that the strain hardening characteristics of these metals can in part be predicted from the monotonic stress-strain behavior but that many of the effects observed are unique to cyclic strain. With respect to the deformation resistance of the metals under cyclic strain, each metal exhibits its own peculiar hardening characteristics associated with the effect of the cyclic straining process on the internal structure of that metal. Some of these metals have been cyclically strained after monotonic deformation. The cyclic strain removes part of the effect of prior deformation, and restores the metal to that state which it would have achieved for the equivalent amount of cyclic strain in the absence of the initial deformation. Fatigue failure most often limits the process from achieving this equilibrium state.

The inverse relationship between plastic strain range and the square root of the number of cycles to failure has been verified in the case of 2S aluminum and AISI type 347 stainless steel for 6 decades of cycles of strain, ranging from ¼ to 2×10^5 cycles. Other metals tested support this relationship, although some deviation is found in the case of OFHC copper at low strain. An abrupt deviation from this relationship at low strain is observed for the two aluminum alloys examined.

Deformation of Lithium-Magnesium Alloy Single Crystals: *S. K. Tung* and *R. Maddin*, University of Pennsylvania.

Magnesium-Lithium alloy single crystals (30, 45.6, and 52.4 at. pct Li) were extended at temperatures from 200 to −190°C. The slip planes, determined at various stages of deformation from stereographic analysis of the slip traces, yielded results which could not be represented as low indices planes. Slip occurred always in the <111> directions. Observations of the slip traces and Laue reflections were made during the deformation.

The shear stress plotted against temperature at constant composition decreases linearly with increasing temperature and becomes approximately horizontal at the elevated temperatures. The variation of yield stress with temperature is discussed in terms of a theory due to Seeger, which permits the calculation of the energy for the intersection of screw dislocations. These are calculated for the alloy compositions used in the present investigation.

Effects of Grain Boundaries in Tensile Deformation at Low Temperatures: *R. L. Fleischer* and *W. A. Backofen*, Massachusetts Institute of Technology.

Effects of grain boundaries on deformation were examined by tensile tests on aluminum single crystals, bicrystals, and polycrystalline specimen at 4.2, 77, and 295°K. Low temperatures are of particular interest for aluminum because at least three well-defined stages of deformation can be encountered, and observations may be made of effects of grain boundaries on the different deformation processes.

It was demonstrated that the compatibility considerations that have been reasonably successful in explaining room temperature grain boundary effects find even more direct application at lower temperatures. The slope and extent of the easy glide region (stage 1) were found to be strongly altered by the grain boundary. On the other hand, a marked similarity was observed in work hardening rates at low temperatures for all test specimens in the linear-hardening stage 11; this is a strong indication that the same work hardening process is of importance for this stage in both single crystal and polycrystal specimens. Except at room temperature, the start of stage 111 appears not to be affected by a grain boundary.

Estimates of the width of the region of multiple slip at an incompatible grain boundary agreed at 4.2, 77, and 295°K. For narrow samples, slightly more than half of the specimen was concluded to have undergone multiple slip. Based on this result, a relationship has been suggested for the width of the multiple-slip region as a function of crystal dimensions.

Influence of an Electrolyte on Deformation Characteristic of Aluminum Single Crystals: *I. R. Kramer* and *L. J. Demer*, Rias, Inc.

Aluminum single crystals were deformed in tension in a chemical polishing bath and their behavior was compared with that of similar crystal deformed in water heated to the same temperature. Back reflection Laue patterns, stress-strain curves and slip line studies were carried out. For the specimens strained in the polishing bath, Laue spots did not exhibit asterism until about 8 pct strain had been reached. In comparison, asterism appeared at much lower strains for specimens tested in water. These observations provide evidence that the oxide coating on the aluminum crystals caused a dislocation pile-up at the surface rather than preventing dislocations sources at the surface from acting. Slip line observations revealed that a greater amount of cross slip had occurred in the specimen tested in the water. For the specimens tested in the polishing both the work-hardening coefficients of stage I and stage II were lower than those obtained for the specimens tested in water.

Effect of Cold Work on the Electrical Resistivity of Copper Solid Solution Alloys: *W. R. Hibbard, Jr.*, General Electric Co.

Measurements of stress and strain during tensile deformation at 78°K and after subsequent recovery treatments suggest that, in solid solution alloys, the higher strength is primarily associated with 1) higher yield stress and, 2) the presence of additional or more effective dislocation barriers in the initial structure, rather than the more rapid or effective generation of dislocation barriers for a given strain during strain hardening. The charactertistics of these dislocation barriers cannot be determined from the experiments, but the alloys may contain: a) more dislocations or slower moving dislocations; b) more vacancy-solute atom combinations; c) smaller substructure; d) localized structure effects such as clustering, short range order, etc.

Measurements of resistivity and strain during tensile deformation at 78°K and after subsequent recovery treatments can be interpreted as follows: 1) more stable point defects occur in the alloys, i.e., the same number are produced in both copper and the alloys but more remain in the alloys; 2) the interaction of the point defects with solute atoms enhances the scattering power of the solute atoms.

Effect of Stress Upon the Recovery and Effect of Negative Strain Upon the Yield Point of Zinc Single Crys-

tals: *J. V. Rinnovatore*, The Electric Storage Battery Co., and *Norman Brown*, University of Pennsylvania.

Zinc single crystals were deformed by pure shear to determine the effect of a stress upon recovery at −50°C. It was found that neither a forward nor a reverse stress in the elastic region affected the rate of recovery. A forward stress beyond the yield point decreased the rate of recovery, and a reverse stress in the plastic region increased the rate of recovery. It was concluded that the rate of dislocation climb determines the rate of recovery.

The process by which a forward stress greater than the instantaneous yield point decreases the rate of recovery is readily explained. Considering that recovery is a process of annihilation of dislocations, a stress large enough to generate dislocations will, in effect, decrease the net amount of recovery. The effect of a large negative stress increasing the amount of recovery is based on the assumption that this stress is sufficiently large to activate the source in sending out dislocations of opposite sign, causing annihilation of the previously piled up array.

In order to test the validity of this proposal, a reverse strain was imposed on the crystal at −72°C to determine its effect on the subsequent yield point in the original direction. The observed decrease in yield point with increasing reverse plastic strain was attributed to an annihilation process.

Calculation of the distance between major obstacles to slip in zinc single crystals, based on the data, gives a value in the order of 10^{-3} in.

Plastic Deformation of Aluminum Multicrystals: *C. Elbaum*, Harvard University.

Aluminum multicrystals, each consisting of two, three or four crystals of a well defined geometry, were plastically deformed in tension at room temperature. The multicrystal specimens were divided into two categories defined by the orientations of the component crystals with respect to each other. In the first category the orientations were choosen in such a way that there was macroscopic compatibility of deformation at the grain boundaries. The axial orientation of each component crystal of a specimen was the same and such that it would be expected to deform on one slip system if it were not part of the multicrystal. In the second category the component crystals were of the same orientation as above, but they were oriented with respect to each other in such a way as to produce the maximum incompatibility of deformation at the grain boundary. The results, and particularly the difference in behavior of the two categories, are interpreted in terms of the geometrical variables of slip and the different dislocation configurations arising in the two cases. The work hardening of the two categories of multicrystals is compared with the work hardening of aluminum single crystals of various orientations, in an attempt to correlate the plastic deformation of polycrystalline materials to that of single crystals.

Effect of Grain Size, Strain Rate, and Temperature on the Yield Point of Columbium: *E. S. Tankins* and *R. Maddin*, University of Pennsylvania.

The yield stress of solid-state purified columbium has been evaluated in the temperature rante 298 to 90°K as a function of grain size and strain rate.

A plot of log stress vs log strain rate results in a linear relationship which fits the equation

$$\sigma_Y = A + B(\dot{\epsilon})^n$$

where σ_Y is the yield stress, A and B are constants, $\dot{\epsilon}$ is the strain rate and n, the strain rate coefficient. The parallelism between the curves indicates that the strain rate sensitivity is independent of grain size.

A discontinuous yield point was observed in the temperature range 298 to 210°K. Below 200°K the yield is no longer discontinuous, i.e., it has no lower yield point. The discontinuous yield point observed above 200°K is typical of other bcc metals. Unloading after reaching the yield point and immediately reloading causes the yield point to disappear. However, if the specimen is unloaded and aged at 500°K for ½ hr, the yield point returns. This yield point is considered to be associated with Cottrell-type locking.

A plot of yield stress as a $f\left(\frac{1}{\sqrt{d}}\right)$, where d is the grain diameter, results in a linear relationship which fits the equation

$$\sigma_Y = C + K(d)^{-1/2}$$

where C and K are constants related to the material. This behavior is explained in terms of dislocations piling up at barriers.

No ductile to brittle transition was observed at temperatures down to 90°K. Good ductility as determined by reduction in area was observed at 90°K.

Cottrell Locking and Yield Stress in Iron: *H. Conrad* and *G. Schoeck*, Westinghouse Electric Corp.

The work of Heslop and Petch has shown that the temperature dependence of Cottrell-locking cannot be measured directly by observing the temperature dependence of the yield stress in α-iron. The reason is that there exists a strongly temperature dependent frictional force σ_i on dislocations which contributes also to the yield stress σ_Y. The temperature dependence of the locking stress σ_c can in principle be determined by measuring the grain size dependence of σ_Y at various temperatures. To obtain such measurements a great number of samples have to be used and measurements have to be made on samples with different thermal and mechanical history.

If there is a strong frictional force σ_i for dislocations in α-iron then this must also contribute to the flow stress of iron under conditions where the dislocations are unlocked by preceding deformation. Especially, a temperature dependence of σ_i should show up in the temperature dependence of the flow stress. Therefore by measuring the difference between flow-stress and yield-stress the frictional stress σ_i can be eliminated. In this way the temperature dependence of the Cottrell locking stress σ_c can be determined directly.

In order to determine in this way the temperature dependence of σ_c, an experimental investigation was made on polycrystalline iron with .05 at. pct C in the temperature region between 4 and 520°K. Identical samples were strained at room temperature to about 5 pct deformation. Part of the samples were then strain aged at 150°C for 1 hr in order to obtain a yield point. The original samples and the strain-aged ones were then further deformed at various temperatures. The difference in the flow-stress and yield-stress is believed to be due to Cottrell locking. The temperature dependence of this locking stress σ_c is found to be much less than the temperature dependence of the yield stress σ_Y in agreement with the measurements of Heslop and Petch.

Aluminum Single Crystals Under Combined Stresses: *U. F. Kocks, R. S. Davis*, and *Bruce Chalmers*, Harvard University.

Torsion-compression tests were carried out on hollow polygonal aluminum single crystals to produce relatively uniform stress states in particular crystallographic directions. Two of these stress states produce the same shear stress on 8 and 6 glide systems, respectively; they are compared with the tensile behavior in the <100> and <111> directions. The result is that there are quite different modes of polyslip which are analyzed in terms of the different arrangement of Lomer-Cottrell locks and the elastic interaction between active glide systems for the different specific glide system combinations.

Some observations on latent hardening in single slip orientations are also reported.

MONDAY, FEBRUARY 16, AM

ISD — Iron Ore Reduction

9:30 am — St. Francis Hotel — Georgian Room

J. E. Stukel and *M. O. Holowaty*, Associate Chairmen
D. E. Babcock, Discussion Leader

Thermodynamics of Direct Reduction Processes: *Kun Li*, Jones & Laughlin Steel Corp.

Kinetics of Iron Oxide Reduction: *W. M. McKewan*, U. S. Steel Corp.

Some Fundamentals of the Reduction of Iron Ore in a Fluidized Bed Reactor: *F. M. Stephens, Jr.*, and *B. G. Langston*, Battelle Memorial Institute.

Staged Countercurrent Systems With Chemical Reactions Occurring—Iron Ore Reduction: *H. P. Meissner*, Massachusetts Institute of Technology, and *F. C. Schora, Jr.*, Arthur D. Little, Inc.

MONDAY, FEBRUARY 16, AM

EMD — Electrolytic Extractive Processes

10:00 am — St. Francis Hotel — Colonial Room

E. D. Dilling and *J. L. Wyatt*, Associate Chairmen

Electrolytic Equilibria and Electrode Behavior in the Soluble Anode Titanium Process: *R. S. Dean, W. W. Gullett, F. X. McCawley,* and *L. D. Resnick,* Chicago Development Corp.

Electrodeposition of Titanium From Fused Chloride Baths Using $TiCl_4$ as a Feed Material: *W. R. Opie* and *K. A. Svanstrom,* National Lead Co.

Fused Salt Electrorefining of Vanadium and Chromium: *D. H. Baker, Jr.* and *F. Cattoir,* U. S. Bureau of Mines.

High-Purity Chromium by Fused Salt Electrolysis: *R. S. Dean, W. W. Gullett,* and *F. X. McCawley,* Chicago Development Corp.

MONDAY, FEBRUARY 16, AM

EMD — Lead

10:00 am — St. Francis Hotel — Italian Room

T. D. Jones and *T. I. Moore,* Associate Chairmen

Up-Draft Sintering of Lead Concentrates and Its Significance for Lead Smelting: *Helmut Wendeborn, M. Peucker,* and *W. Massion,* Lurgi Gesellschaft, Frankfurt-am-Main, Germany.

Chemistry of Lead Blast Furnace Dross Formation and Retreatment: *J. H. Reed* and *G. H. Turner,* Consolidated Mining and Smelting Co. of Canada Ltd.

Spectrochemical Slag Analysis With the Tape Technique: *Allan Danielson, I. Nilsson,* and *G. Sundkvist,* Bolidens Gruvaktiebolag, Sweden.

MONDAY, FEBRUARY 16, PM

IMD

Symposium on Direct Observations of Dislocations

2:30 pm — St. Francis Hotel — California Room

B. D. Cullity and *M. E. Fine,* Chairmen

Direct Observations of Dislocations With the Electron Microscope: *H. G. F. Wilsdorf,* Franklin Institute.

Dislocations and other crystal defects can be seen directly in thin foils by means of transmission electron microscopy, and the mechanism of contrast formation will be discussed briefly. A review of the experimental aspects will cover the various methods that have been used to produce dislocations and stacking faults in suitable specimens. The techniques by which dislocations can be made to move through the foils while they are being observed on the fluorescent screen will receive particular attention.

Starting with some observations on thin films produced by evaporation, the emphasis of the review will be on results obtained from foils prepared from bulk material. In annealed specimens most of the dislocations are arranged in sub-boundaries, and the determination of dislocation densities is somewhat ambiguous. At the beginning of plastic deformation most glide dislocations originate from these sub-boundaries. Dislocation pile-ups have not been observed in deformed thin foils, and an explanation for the phenomenon will be given. Dislocations frequently turn from their original slip system into the cross-slip system and back, if their path is blocked by other dislocations. Occasionally, glide on non-octahedral planes has been observed. Some dislocation reactions will be reported. The fracture of thin foils has been studied and three different mechanisms have been found to operate.

Finally, a discussion of results obtained on quenched metals, polygonization boundaries, stress fields around Guinier-Preston zones and domain structures in copper-gold alloys will be given.

Distribution of Dislocations in Deformed Metals: *P. B. Hirsch,* Cavendish Laboratory, Cambridge, England.

The electron microscope transmission technique for the study of dislocations in metals has been applied to a number of metals deformed in various ways. A study of the dislocation distributions in polycrystalline FCC metals deformed at room temperature has shown that the dislocations are arranged in pile-ups (at low deformations) and networks on the slip planes in metals of low stacking fault energy, and in cell boundaries in metals of high stacking fault energy. Preliminary results on deformed single crystals will also be reported. Some ideas on the formation of these networks will be discussed.

Preliminary results have been obtained on a study of the variation of the dislocation distribution with depth below the surface, and a technique will be described whereby slip lines and the dislocations below the surface can be seen at the same time.

Some experiments have been carried out on the dislocation distributions in fatigued aluminum, and the results will be compared with those obtained from specimens deformed in unidirectional tension.

Dislocations in Graphite: *Alexander Grenall,* Atomic International, Div. of North American Aviation, Inc.

Direct observation by electron microscopy has revealed the presence of dislocations in graphite. The nature of these dislocations and their movement within the structure of the crystals have been studied and recorded by motion pictures. The techniques employed are described and a 25 min movie gives some of the results obtained on natural graphite.

The driving force for producing dislocation motion is supplied by thermal stresses set up by the electron beam. The crystals are examined by transmission at magnifications of 12,500 and 25,000 times.

Examples are shown of single dislocations occurring within a crystal grain and moving in glide and climb.

Animated scenes give illustrations of postulated mechanisms of edge and screw type dislocations lying in the basal and prism planes. Dislocation formation is related to the microstructure of graphite.

Complex arrangements of dislocations and movement of some of these dislocations are illustrated. Sub-grain boundaries composed of aligned single dislocations are shown. The high mobility of this type of boundary is seen. Examples of dislocation nodes, networks of dislocations, and stress generators are given.

Throughout the electron microscope motion pictures many other dislocations features are seen and fully demonstrate the existence of dislocations in graphite.

Observations of Dislocations by Means of X-Rays, Decoration, and Etch-Pitting: *W. G. Johnston,* General Electric Co.

These three techniques for observing dislocations in large crystals will be described, and examples will be shown from the work of various investigators at the General Electric Research Laboratory. The Berg-Barrett X-ray method has been used by J. B. Newkirk to reveal dislocations in several materials. A simple apparatus is used to photograph a beam of characteristic X-rays reflected from the specimen. The dislocation structure shows up in detail because there is enhanced scattering of X-rays from the distorted region about a dislocation. The intensity of scattering from a dislocation depends upon the orientation of the Burgers vector with respect to the diffracting planes. Therefore, the direction of the Burgers vector can be determined by this method.

The decoration method is useful for examining transparent crystals in which an impurity can be precipitated onto the dislocations. The dislocations then appear as threads of precipitate running through the crystal. W. C. Dash has examined deformed crystals of silicon, decorated with copper, and viewed with infrared light. The dislocation sources during deformation appear to be of the types suggested by Frank and Read, as well as surface sources formed during preparation of the specimens.

R. W. Guard and J. R. Low have recently etched dislocations lying parallel to the surface of a crystal, so that large portions of dislocation loops are revealed by one etching. This technique has been useful in studying the formation and structure of glide bands in Fe-Si crystals. J. J. Gilman and W. G. Johnston have been able to trace dislocation movements in LiF by repeated etchings, so that individual dislocation velocities can be measured. The velocities have been measured as a function of applied stress over twelve orders of magnitude in velocity. From this information, and measurements of dislocation density as a function of strain, it is possible to predict a flow curve for a crystal in terms of the observed properties of individual dislocations.

MONDAY, FEBRUARY 16, PM

IMD-EMD

Symposium on Beryllium

2:30 pm St. Francis Hotel Borgia Room

A. R. Kaufmann, Chairman

Problem Areas in Beryllium Technology: *J. Conner*, Wright Air Development Center.

High Purity Beryllium: *H. Sumsion*, Lockheed Aircraft Corp.

Beryllium-Base Alloys: *W. Beaver*, Brush Beryllium Co.

High-Temperature Anomaly in Beryllium: *S. Gelles*, Nuclear Metals, Inc.

Fracture Studies on Beryllium Single Crystals: *S. Gelles*, Nuclear Metals, Inc.

Surface Damage and Crack Propagation: *C. Mathews*, Lockheed Aircraft Corp.

Solidification Studies on Beryllium: *F. A. Crossley, W. H. Graft*, and *A. G. Metcalfe*, Armour Research Foundation.

Brazing and Welding of Beryllium: *S. Maloof*, Avco Manufacturing Corp.

Composite Materials of Beryllium: *J. Greenspan*, Nuclear Metals, Inc.

Casting of Beryllium Billets: *W. Santschi*, Beryllium Corp. of America.

Progress Report on Rolling and Properties of Pure Beryllium Sheet: *C. Schwenzfeier*, Brush Beryllium Co.

A Study of the Forging of Beryllium: *A. Hayes*, Ladish Co.

Development of Shaped Beryllium Extrusions: *J. Van Hamersveld*, Northrop Aircraft, Inc.

MONDAY, FEBRUARY 16, PM

ISD-EMD

Iron Blast Furnace Engineering

2:30 pm St. Francis Hotel Georgian Room

L. Tofft, Discussion Leader

J. B. Wagstaff and *J. D. Saussaman*, Associate Chairmen

Nitrogen Quench of Bureau of Mines Experimental Blast Furnace: *J. J. Bosley*, U. S. Steel Corp., *N. B. Melcher*, U. S. Bureau of Mines, and *M. M. Harris*, U. S. Steel Corp.

Oxygen Enrichment of Blast for Ferro-Manganese Production: *J. M. Stapleton, R. J. Flanagan, R. L. Stephenson*, and *Dugal Fletcher*, U. S. Steel Corp.

Basic Characteristics of Ferrous and Non-Ferrous Blast Furnacing: *W. O. Philbrook*, Carnegie Institute of Technology.

A New Correlation of Blast Penetration in a Blast Furnace: *G. C. Gardner*, U. S. Steel Corp.

MONDAY, FEBRUARY 16, PM

EMD-IMD

Plutonium—Extractive Metallurgy

2:30 pm St. Francis Hotel Colonial Room

B. Blumenthal and *W. D. Wilkinson*, Associate Chairmen

Plutonium Metal Preparation: Motion Picture by Los Alamos Scientific Laboratory.

This 12 min motion picture depicts the facilities and process of the Los Alamos facility for the remotely-controlled conversion of plutonium nitrate to plutonium metal. Plutonium nitrate in nitric acid solution is treated with 30 pct H_2O_2 solution to precipitate plutonium(IV) peroxide. This peroxide is directly converted to plutonium(IV) fluoride by reaction with hydrogen fluoride at 600°C. The fluoride powder is then mixed with calcium and iodine booster in a reduction bomb and fired to yield a 300-g button of plutonium. Metal of 99.8 pct purity by weight is routinely produced at a yield of 98 pct in this facility.

Calcium Reduction of Plutonium Halides to Metal: *R. D. Baker, A. N. Morgan*, and *W. J. Maraman*, Los Alamos Scientific Laboratory.

Essentially all of the plutonium metal currently produced in the US is prepared by calcium reduction of a halide of plutonium. The development of this process during the period 1943 to 1946 is reported and compared with current technology. Methods and equipment used to prepare metal of greater than 99 wt pct purity in good yield from either plutonium(III) chloride of plutonium(IV) fluoride are presented. The effects of process variables such as reduction scale (varied from 1 to 500 g plutonium), the use of iodine as a booster, reduction temperature-time cycle, purity of halide, and crucible properties on the product yield and purity are also discussed.

Preparation of Plutonium Metal: *F. Anselin*, Centre d'Etudes Nucleaires, Fontenay-aux-Roses, (Seine), France.

Alternative Routes for the Conversion of Plutonium Salts to Metal and Their Recovery Problems: *I. L. Jenkins, N. Keen*, and *A. G. Wain*, Atomic Energy Research Establishment, Harwell, England.

Routes for the production of plutonium metal from various salts are discussed. Many of these can be eliminated as unsuitable for routine production for various reasons, e.g. the formation of infusible slags and the occurrence of finely divided metal. The recovery problems associated with the fluoride and chloride routes are outlined.

Distribution of Plutonium and Selected Impurity Elements Between Nitrate Solutions and Tri-N-Butyl Phosphate: *E. L. Christensen, C. W. Kelley, A. J. Beaumont*, and *J. R. Humphrey*, Los Alamos Scientific Laboratory.

Solvent extraction of plutonium from nitric acid solutions with tri-n-butyl phosphate in kerosene is an important purification method in the recovery and preparation of plutonium metal. In this study the distribution coefficients of impurities frequently encountered in plutonium were measured at various HNO_3 and $Al(NO_3)_3$ salting agent concentrations. By properly adjusting the HNO_3 and $Al(NO_3)_3$ concentrations, good separation of Cr, Ni, Cu, Fe and Ce are attainable in a single extraction step. Separation of Zr, Th and U are unsatisfactory over the range of process variables studied.

Preparation of Anhydrous Plutonium Halides for Fused-Salt Studies: *J. G. Reavis, A. N. Morgan, A. E. Ogard, K. W. R. Johnson, K. A. Walsh*, and *J. A. Leary*, Los Alamos Scientific Laboratory.

Methods and equipment for preparing anhydrous high-purity plutonium(III) fluoride, plutonium(IV) fluoride, plutonium(III) chloride and plutonium(III) bromide on a 100- to 300-g scale for use in fused salt studies are discussed. Plutonium(III) fluoride was prepared from aqueous solution by precipitation of either plutonium(III) oxalate or plutonium(IV) peroxide, followed by treatment with gaseous hydrogen fluoride and hydrogen. Good yield and purity were obtained when these reactions were conducted at 600°C. Plutonium(IV) fluoride also has been prepared from aqueous solution by precipitating plutonium(IV) peroxide and passing hydrogen fluoride and oxygen over the peroxide. Although this reaction can be conducted at temperatures as low as 150°C, conversion at 600°C is more rapid and yields a better product. Plutonium(III) chloride and plutonium(III) bromide have been prepared from plutonium by hydriding the metal at 200°C, followed by reaction of the hydride with dry hydrogen halide at 450°C. Additional purification is possible by vacuum distillation of the chloride and the bromide. Yields, purities and properties of all preparations are presented.

Removal of Fission Product Elements From Plutonium by Liquation: *J. A. Leary* and *K. W. R. Johnson*, Los Alamos Scientific Laboratory.

The economic utilization of plutonium as a fuel in high-burnup breeder reactors will depend to a large degree on developing economical fuel reprocessing methods. For high-burnup applications, it is possible that the concentrations of some fission products may exceed the normal solubilities in the molten fuel alloy. Significant purification may be realized by the simple process of liquation, followed by a mechanical separation step such as filtration.

Liquation experiments have been conducted with a synthetic spent plutonium fuel *fissium*, made from the basic 9.5 at. pct iron —plutonium alloy that is typical of the fuel proposed for the Los Alamos Molten Plutonium Reactor Experiments. Fission product elements were added in an amount corresponding to 10 pct burnup of the plutonium. Experimental results indicate that zirconium, molybdenum, and lanthanum are relatively insoluble in the molten alloy at 550°C, while ruthenium, cerium, and iron concentrations are affected only slightly by liquation.

MONDAY, FEBRUARY 16, PM

EMD — Copper

2:30 pm — St. Francis Hotel — Italian Room

R. J. Stevens, Chairman

Operations at the Mufulira Smelter With Special Reference to the Latest Reverberatory Furnace Practice: *D. L. Turnbull*, Mufulira Copper Mines Ltd., Northern Rhodesia.

Operations at Mt. Isa Mines, Ltd.'s Copper Smelter: Mt. Isa Mines Ltd., Australia.

New Tough Pitch Continuous Copper Casting Unit at ASARCO's Perth Amboy Plant: *G. D. Storm* and *J.R. Stone*, American Smelting and Refining Co.

Electrolytic Copper Refining at High Current Densities: *S. J. Wallden, S. T. Henriksson, P. G. Arbstedt*, and *T. Miöen*, Bolidens Gruvaktiebolag, Sweden.

Blister Copper Production at Union Miniere du Haut-Katanga From Kipushi Mine Ores: *L. J. Steygers, J. Lichtherte*, and *J. Hubin*, Union Miniere du Haut-Katanga, Belgian Congo.

TUESDAY, FEBRUARY 17, AM

IMD

Research Summaries on Observations of Dislocations

(Based on Submission of Research Abstracts)

9:00 am — St. Francis Hotel — California Room

T. L. Johnston, Chairman

A Comparison Between Results Obtained by Etching Deformed LiF Crystals With a Theory of Dislocation Production From Sheets of Condensed Vacancies: *D. Kuhlmann-Wilsdorf, R. Maddin*, University of Pennsylvania, and *H. Kimura*, University of Tokyo.

Recently, a new theory was presented explaining the origin of those dislocations which arise during the plastic deformation of crystals. It rests on the idea that thermal vacancies, on cooling, condense into single layers parallel to the most densely packed lattice planes. As the two sides of such layers collapse and fuse again prismatic dislocations (named *R*-dislocations or *R*-loops) are generated which represent dislocation sources of the Frank-Read type. Although this theory has been greatly strengthened by the recent discovery in several metals of the predicted *R*-dislocations there is, as yet, no proof that the *R*-dislocations are in fact the sources for dislocations during the plastic deformation of crystals. So far, the major counter arguments are based on the extensive investigations by Gilman and Johnston on etched, deformed LiF crystals. Hence, it seemed desirable to determine whether or not the published findings on LiF contradict the theory of *R*-loops as disclosed sources. A study of this problem led to a self consistent semi-quantitative interpretation of the published results of Gilman and Johnston in terms of *R*-loops.

Calculations of Dislocation Pile-Ups: *D. Kuhlmann-Wilsdorf*, University of Pennsylvania.

Under the action of a uniform shear stress dislocations of like type and sign, lying on the same slip plane, will pile-up behind obstacles on that plane. The equilibrium positions of any one of the dislocations in a pile-up thereby is reached when the resultant shear stress due to all the other dislocations is equal and opposite to the applied shear stress. Thus, in order to determine the equilibrium positions of n like dislocations behind a leading dislocation held up at $x = 0$, a set of n-1 equations of the form

$$\sum_{\substack{j=1 \\ j \neq i}}^{n} \frac{1}{x_i - x_j} = C$$

has to be solved, where C is a constant involving the Burgers vector of the dislocations, the applied shear stress and the elastic constants of the material considered. So far this set of equations had remained unsolved except for quite small values of n. Approximate solutions had been given for large n. Very recently the problem was solved with an electronic calculating machine for n up to 70. The results are presented and compared with the approximate solutions given previously.

Fatigue Processes in Ionic Crystals: *I. Cornet* and *A. E. Gorum*, University of California.

Fatigue of ionic crystals has been studied, primarily in magnesium oxide, in a manner paralleling classical studies of fatigue of aluminum, copper, and other metals. Under cyclic stress, dislocations move irreversibly, they multiply, slip bands form and grow, cracks nucleate and propagate, and failure occurs. These processes correspond to processes observed or hypothesized in metals.

The use of ionic crystals such as MgO is advantageous in such investigation because they are optically transparent; they show stress birefringence; it is comparatively simple to bring out dislocation intersections with (100) surfaces by etch pit and shadowing techniques, and these features may be observed with standard microscope techniques. Ionic single crystals investigated so far have been of cubic structure; they form much fewer slip lines and bands than is common in metals, and the slip is less uniform in distribution within a crystal. While ionic crystals ordinarily fail by cleavage in tension, they often show what appear to be shear failures as well as cleavage under cyclic stress. Cyclic stress also develops more numerous and more widely distributed slip lines and bands than does tension alone in these materials.

The movement of dislocations perpendicular to a fatigue crack has been noted. While cracks may originate at the intersection of dislocation lines and slip bands, it has not yet been possible to predict successfully at which such intersection the crack which will ultimately cause fracture will initiate. Also, in ionic crystals there appears to be evidence that cracks may start in the interior of the crystal; in contrast in copper and in aluminum single crystals, fatigue cracks appear to originate at or near the surface.

TUESDAY, FEBRUARY 17, AM

IMD

Research Summaries on Mechanical Properties

(Based on Submission of Research Abstracts)

9:00 am — St. Francis Hotel — Borgia Room

J. E. Dorn, Chairman

Fracture of Metals Under High-Speed Loading Conditions: *J. L. O'Brien* and *R. S. Davis*, Harvard University.

Modifications of the *Hopkinson Bar Technique*, previously used by Rinehart for the evaluation of the stress for fracture under explosive loading conditions, have resulted in stresses for fracture of various metals that are considerably higher than those values reported by Rinehart. For example, Rinehart reported a stress for fracture of a hardened Al - 5 pct Cu alloy, under these loading conditions, of 140,000 psi, whereas, the authors obtained a value of 240,000 psi. The stress for fracture of the Al - 5 pct Cu alloy is not significantly different from the fracture stress for a high purity polycrystalline aluminum specimen.

Techniques have also been developed to obtain quantitative information on the energy for fracture and the rate of crack propagation, under these loading conditions.

Temperature and Strain-Rate Dependence of the Flow Stress of Magnesium Crystals: *R. Armstrong, H. Conrad, H. Wiedersich*, and *G. Schoeck*, Westinghouse Electric Corp.

It has been proposed that the rate-controlling mechanism for low temperature deformation of HCP metal crystals is the intersection of dislocations. This theory predicts that $\frac{\partial \sigma}{\partial T}$ is a constant and that $\frac{\partial \sigma}{\partial \ln \dot{\epsilon}}$ is proportional to the temperature, where σ is the flow stress, T the temperature, and $\dot{\epsilon}$ the strain rate. The temperature dependence of the flow stress observed experimentally is in agreement with the theory. However, recent work by Conrad and Robertson on the creep of Mg crystals has indicated that $\frac{\partial \sigma}{\partial \ln \dot{\epsilon}}$ is independent of the temperature, in disagreement with the predictions of the theory. In order to clarify this discrepancy the present investigation was undertaken.

In the present work, temperature-change and strain-rate-change tests were employed every 20° in the range 80 to 420°K to investigate in considerable detail the effect of temperature on the parameters $\frac{\partial \sigma}{\partial T}$ and $\frac{\partial \sigma}{\partial \ln \dot{\epsilon}}$. It was found that the flow stress versus temperature curve showed a slight positive curvature, indicating that $\frac{\partial \sigma}{\partial T}$ decreased slightly with increase in temperature. In agreement with the earlier work, the parameter $\frac{\partial \sigma}{\partial \ln \dot{\epsilon}}$ was independent of stress, strain, and temperature. A modification of the existing theory is discussed in light of these experimental results.

Activation Energy for Frank-Read Source Generation in Pure Aluminum: *R. Rosenberg* and *I. Cadoff*, New York University.

The torsional after-effect experiment was used as a means of measuring magnitudes of dislocation pile-ups which occur during plastic flow. The rate controlling process for untwisting or movement of dislocations from a pile-up is governed by an activation-type equation in which the activation energy is not constant, but is dependent upon the density of dislocations remaining in the pile-up at any time during untwist. Use of the above relation permits evaluation of the relative magnitudes of dislocation pile-up under varying conditions.

In high purity aluminum, an increase in the testing temperature was found to result in an increase in dislocation pile-up. If holding time after twist, τ, is maintained constant over the range of temperature, an Arrhenius type function is obtained where $\ln p$ is proportional to $1/T$, the magnitude of pile-up being expressed by p and the temperature by T. Constant temperature tests on specimens in which the percent impurity at the Frank-Read sources was varied indicated that the pile-up obtained at any temperature was not significantly affected by the small amount of impurity present in the material; therefore, the Frank-Read sources must be temperature as well as stress activated. An increase in τ at the various temperatures resulted in an increase in the magnitude of the pile-up obtained, but the Arrhenius functions for various constant delay times showed an increase in energy required for additional dislocation generation with increase in τ. At a constant temperature, this results in a decrease in the rate of dislocation pile-up with τ, the actual relation showing that the number of dislocations entering a pile-up is dependent upon the number previously piled-up and decreases logarithmically with time. Extrapolating the activation energies obtained at various delay times to a delay time in the order of 0.015 min yields an activation energy which compares with reported values of the activation energy for yielding of pure aluminum.

An expression relating the movement of dislocations into a pile-up, with delay time, temperature, the number of dislocations in the pile-up, and the activation energies involved in the process is obtained.

Yield Point Phenomenon in Germanium: *J. N. Hobstetter*, University of Pennsylvania.

In the course of a study of the introduction of point defects into germanium, a classical yield point phenomenon was observed during a tensile test and is here reported for what appears to be the first time.

The specimen consisted of a thin, long, slab-shaped single crystal of Sb-doped, p-type germanium containing about 10^{15} carriers per cu cm. It was oriented for single slip with the axis about [123] and a (111) face exposed. The test was conducted on an Instron machine at 650°C in an atmosphere of nitrogen. An elongation rate of 0.05 in. per min gave an upper yield of 7600 psi followed by a fairly rapid decrease to a lower yield point of 4500 psi, a drop of about 40 pct. Immediate reloading caused further flow at the lower yield point with slow work hardening. Unloaded aging at 650°C for several minutes partly restored the upper yield point. The yield phenomenon was not present at slower elongation rates and became pronounced at faster rates.

The lower yield point at this temperature was found to depend on elongation rate as: $YP = 6500 + 1500 \log \dot{L}$.

Deformation Modes of Zirconium at 78°K, 300°K, and 573°K: *E. J. Rapperport*, Nuclear Metals, Inc.

A study has been made of the deformation processes active in zirconium deformed in tension at 78, 300, and 573°K. The work was performed on large grained samples of arc-melted and forged iodide crystal-bar, with a wide orientation distribution.

The only slip system observed at any of the test temperatures was $\{10\bar{1}0\}\langle\bar{1}2\bar{1}0\rangle$ with a critical resolved shear stress of about 1.0 Kg per sq mm at 78°K, and 0.2 Kg per sq mm at 573°K, compared to a value of 0.65 Kg per sq mm reported before for 300°K. Although some of the crystals were particularly well oriented for basal slip, none was observed at any of the test temperatures. The active twin planes at each of the three temperatures are {1012}, {1121}, {1122}, and {1123}. At 78°K the principal twin mode is {1121} with a moderate amount of $\{11\bar{2}2\}$ activity, less $\{10\bar{1}2\}$ evident, and very little {1123}. At 573°K the principal twin mode is {1012}, with moderate {1121} activity, and very little {1122} and {1123}. At 300°K {1121} was the most active plane, followed by {1012}, with little {1122} and even less $\{11\bar{2}3\}$.

TUESDAY, FEBRUARY 17, AM

EMD-IMD

Plutonium—Physical Metallurgy

9:00 am St. Francis Hotel Italian Room

F. W. Schonfeld and *W. D. Wilkinson*, Associate Chairmen

Some Principles of the Alloying Behavior of Plutonium: *J. T. Waber*, Los Alamos Scientific Laboratory.

The tendency of plutonium to dissolve alloying elements in its FCC (delta) and BCC (epsilon) phases is discussed in terms of atomic radii and electro-negativities. The tendency to form immiscible liquids with other elements is analyzed by Mott's extension of Hildebrand's method. These findings are compared with the available phase diagrams for plutonium. Some consideration is given to the Brillouin Zones of several plutonium allotropes.

Behavior of Some Delta-Stabilized Plutonium-Rich Alloys at High Pressures: *R. O. Elliott* and *K. A. Gschneidner, Jr.*, Los Alamos Scientific Laboratory.

A number of Pu-rich alloys have been examined under pressures up to 10,000 atm in order to study the effects of different alloying additions on the stabilization of delta-phase plutonium at room temperature. The compressibilities and transformation pressures of these alloys were determined both as a function of composition and of alloying element. The natures of the observed transformations are discussed.

Metallography of Alpha Plutonium: *P. Bardet, H. Monti, A. Robillard*, and *F. Sebilleau*, Centre d'Etudes Nucleaires, Fontenay-aux-Roses (Seine), France.

Etching of Plutonium and Plutonium Alloys by Cathodic Bombardment: *K. Imlah*, Los Alamos Scientific Laboratory.

Plutonium-Cerium Phase Diagram: *F. H. Ellinger, C. C. Land*, and *E. M. Cramer*, Los Alamos Scientific Laboratory.

Thermal, dilatometric, X-ray diffraction, and metallographic techniques have been utilized in establishing the phase relationships in Pu-Ce alloys. The phase diagram is characterized by a eutectic, no intermediate phases, and extensive solid solubility of Ce in δ-Pu and of Pu in β-Ce (FCC). The solubility of Ce in δ-Pu decreases from a maximum of 24 at. pct Ce at 502°C to 18 at. pct Ce at 250°C. δ-Pu containing 7 at. pct Ce or more is stable at room temperature. The solubility of Pu in β-Ce decreases from a maximum of 20 to 25 at. pct Pu at 590°C to 7 at. pct Pu at 250°C.

The important isothermal reactions in the system may be described as follows (the subscripts denote the composition in at. pct Ce):

1) Eutectic at 625°C, $L_{18} \simeq \epsilon\text{-Pu}_{16} + \beta\text{-CE}_{\sim 75}$
2) Peritectoid at 592°C, $\epsilon\text{-Pu}_{12} + \beta\text{-Ce}_{\sim 75} \simeq \delta\text{-Pu}_{24}$
3) Inverse peritectic at 719°C, $\gamma\text{-Ce}_{(?)} \simeq L_{64} + \beta\text{-Ce}_{(?)}$

Plutonium-Zinc Phase Diagram: *E. M. Cramer, F. H. Ellinger*, and *C. C. Land*, Los Alamos Scientific Laboratory.

Some Experiments on the Zone Refining of Plutonium: *R. E. Tate* and *R. W. Anderson*, Los Alamos Scientific Laboratory.

The zone melting process has been applied to plutonium containing known amounts of impurities and the segregation of these impurities determined by chemical and spectrographic analyses. Rod specimens of plutonium were contained in thoria or in carbide-coated tantalum boats. Each rod was passed horizontally through a single-turn, high-frequency coil in such a manner as to cause a narrow molten zone to pass repeatedly through the rod. The impurity elements Al, Co, Cr, Fe, Mn, Ni, and Si were found to move in the directions predicted from the respective binar constitutional diagrams. It is shown that, for the equipment used, only at a rate of zone travel of less than ¼ in. per hr do the experimentally obtained distribution coefficients begin to approach those calculated from the constitution diagrams.

TUESDAY, FEBRUARY 17, AM

EMD
Symposium on Gases in Light Metals

9:00 am St. Francis Hotel Olympic Room

W. S. Peterson, Moderator

Causes of and Solubility of Gases in Aluminum and Magnesium: *R. S. Busk*, The Dow Chemical Co.

Measurement of Gas in Molten Metal by the Vacuum Gas Test: *C. L. Brooks*, Reynolds Metals Co.

New Rapid Methods of Measuring Gas in Molten Metal: *C. E. Ransley*, The British Aluminium Co. Ltd.

Degassing Agents for Molten Light Metals: *J. E. Dore*, Olin Mathieson Chemical Corp.

Processes for Degassing Commercial Size Melts: *J. J. Wegner*, Kaiser Aluminum and Chemical Co.

TUESDAY, FEBRUARY 17, AM

ISD
Basic Oxygen Steel

9:00 am St. Francis Hotel Colonial Room

H. W. Graham and *Barney Dagan*, Associate Chairmen

Operation of the Basic Oxygen Furnaces, Aliquippa Works, Jones & Laughlin Steel Corp.: *D. R. Loughrey*, Jones & Laughlin Steel Corp.

Role of High-Purity Oxygen in Metallurgical Processes: *H. B. Emerick*, Jones & Laughlin Steel Corp.

ISD
Howe Memorial Lecture

11:00 am St. Francis Hotel Colonial Room

Howard C. Pyle and *K. L. Fetters*, Associate Chairmen

Speaker: *C. E. Sims*, Battelle Memorial Institute.

Subject: *The Nonmetallic Constituents of Steel.*

ISD
Annual Luncheon and Business Meeting

12:15 pm St. Francis Hotel Georgian Room

K. L. Fetters, Chairman, Presiding

Speaker: *J. L. Mauthe*, Chairman of Board, Youngstown Sheet and Tube Co.

Subject: *Reflections on Half a Century of Steelmaking.*

WEDNESDAY, FEBRUARY 18, AM

EMD-ISD
Kinetics in Extractive Metallurgy

9:00 am St. Francis Hotel California Room

T. B. King and *Gerhard Derge*, Associate Chairmen

Exchange Reactions in Molten Salt-Molten Alloy Systems: *T. B. King* and *A. Morkel*, Massachusetts Institute of Technology.

Exchange Studies Between Bismuth-Rare Earth Alloys and Fused Salts: *H. Katz, F. Hill*, and *J. L. Speirs*, Brookhaven National Laboratory.

Rate of Oxidation of Solutes in Bismuth: *D. Schweitzer* and *D. H. Gurinsky*, Brookhaven National Laboratory.

Rate of Solution of Nickel-Copper Alloys in Molten Lead: *D. Stevenson* and *J. Wulff*, Massachusetts Institute of Technology.

A Note on the Kinetics of Nitrogen Absorption in Liquid Iron: *J. C. Humbert* and *J. F. Elliott*, Massachusetts Institute of Technology.

WEDNESDAY, FEBRUARY 18, AM

EMD
Occurrence, Beneficiation, and Separation of Rare Earths

9:00 am St. Francis Hotel Italian Room

H. E. Kremers, Chairman

Occurrence, Mining, and Marketing of the Yttrium Rare Earths: *J. H. Whitman*, Michigan Chemical Corp.

Production and Uses of Rare Earths: *P. R. Kruesi*, Heavy Minerals Co.

Mining and Beneficiation of Bastnasite, and Its Industrial Possibilities: *E. A. Lucas* and *Harold Bailey*, Molybdenum Corp. of America.

World Reserves of the Rare Earth Metals: *R. J. Anderson*, Battelle Memorial Institute.

Liquid-Liquid Solvent Extraction of Rare Earth Elements: *D. J. Bauer, A. C. Rice*, and *J. S. Berber*, U. S. Bureau of Mines.

Preparation of Pure Cerium Dioxide from Bastnasite by Solvent Extraction: *H. G. Petrow, Peter Rigopolas*, and *John Frederickson*, Ionics, Inc.

Metallography of the Rare Earth Metals: *C. Kirkpatrick* and *V. Novy*, Research Chemicals, Inc.

WEDNESDAY, FEBRUARY 18, AM

EMD — Zinc

9:00 am — St. Francis Hotel — Olympic Room

J. W. Hanley and *R. R. McNaughton*, Associate Chairmen

Hemiska Industrija Zorka Electrolytic Zinc Plant: *A. H. Kunkel, Jr.*, Singmaster and Breyer, and *Gligorije Stankovic*, Hemiska Industrija Zorka.

Josephtown Electrothermic Zinc Furnaces: *C. D. Henderson*, St. Joseph Lead Co.

Some Physical Chemical Aspects of Zinc Blast Furnace Operation: *S. W. K. Morgan* and *John Lumsden*, The National Smelting Co., Ltd., Avonmouth, England.

Improvements in Vertical Retort Process for Zinc Smelting: *G. T. Mahler, J. A. Marvin, Jr.*, The New Jersey Zinc Co., *Marcel Marechal*, and *Georges Biquet*, Compagnie Royale Asturienne des Mines, France.

FluoSolids Roasting of Zinc Sulfides: *D. MacAskill*, Dorr-Oliver, Inc.

WEDNESDAY, FEBRUARY 18, AM

IMD Research Summaries on Alloys Strengthening

(Based on Submission of Research Abstracts)

9:00 am — St. Francis Hotel — Borgia Room

T. H. Hazlett, Chairman

Creep-Rupture Tests at 1800°F and 2000°F on Hyper-Pure Silicon Polycrystals: *J. T. Brown*, Westinghouse Electric Corp.

Data on the creep-rupture strength and ductility of polycrystalline specimens of 99.999+ pct Si is presented. Tests were conducted at 1800 and 2000°F at stresses between 7500 and 9500 psi. Rupture times from 3 to 450 hr are reported with rupture elongations from 16 to 102 pct.

Conventional stress-rupture curves are constructed from the results. Also a plot of stress:density ratio versus temperature is used to illustrate the superiority of the silicon over a molybdenum-titanium alloy. The excellent oxidation resistance of silicon is discussed, but its extreme brittleness up to 1600°F is the chief deterent to its use as a structural material.

The method used to grow the specimens is described, and macro photographs showing the grain structure and different types of strain markings are presented.

A brief discussion of the probable mechanisms which inhibit deformation, and the mechanisms by which deformation takes place in silicon is given. Co-valent bonding in the diamond cubic crystal structure inhibits straining. Conventional slip seems to be the principal deformation mechanism even at 2000°F.

The activation energy for creep calculated from the rupture time relationship $t_R e^{\frac{-\Delta H}{RT_1}} = t_R e^{\frac{-\Delta H}{RT_2}}$ is found to be 140 K cal per mole.

Mechanical Behavior of Whiskers at Elevated Temperatures: *S. S. Brenner*, General Electric Co.

The effect of temperature on the mechanical behavior of copper and iron whiskers has been investigated. The whiskers were tested either in tension or bending. The results obtained thus far indicate that at elevated temperatures the whiskers are still many times stronger than bulk crystals but only few can be strained elastically in excess of one percent. Failure at elevated temperatures occurs as at room temperature at very localized regions which may be flaws on the surfaces. The effectiveness of these flaws to cause yielding appears to increase rapidly with temperature. The effects of surface films and environment on the temperature dependence of the strength will be discussed.

Short-Time Creep-Rupture Behavior of Tungsten and Molybdenum at High Temperatures: *W. V. Green, M. C. Smith*, and *D. M. Olson*, Los Alamos Scientific Laboratory.

The creep-rupture behaviors of commercial powder metallurgy tungsten and molybdenum are reported. Test temperatures were 2250 to 2800°C, stresses were up to 7,000 psi, and times were up to 4 hr for tungsten. For molybdenum, test temperatures were 1600 to 2500°C, stresses were up to 11,000 psi and times were up to 1 month. The creep tests were performed in a constant load testing machine previously described by Smith, Olson, and Brown. In it, the specimen is heated by radiation from an electrically heated heater tube and stressed in tension in a helium atmosphere or vacuum. Periodic gage-length measurements are made with a pair of cathetometers.

The resulting creep curves generally showed very little first stage creep, moderate amounts of second stage creep, and terminated in third stage creep. Fracture occurred by intercrystalline fracture. Total elongations generally were 15 to 25 pct for tungsten and 5 to 15 pct at 2000°C and above and 30 to 50 pct at 1600 to 1700°C for molybdenum.

Abnormal grain growth occurred during some tests on molybdenum specimens.

For each test temperature and metal, the second stage engineering creep rates are shown as a function of initial stress on a log-log plot. True minimum creep rates are shown as a function of true creep stresses corresponding to these rates in a similar manner. These true minimum creep rates in sec^{-1} are given by

$$\dot{\epsilon} = 1.34\,\sigma^{6.5}\,e^{-100,000/RT} \times 10^{-11}$$

for tungsten and by

$$\dot{\epsilon} = 2.95\,\sigma^{4.5}\,e^{-114,000/RT} \times 10^{-5}$$

for molybdenum where σ is the true stress in psi corresponding to $\dot{\epsilon}$, T the temperature in °K and R the gas constant. These are least-square error fitted results.

Rupture time is shown as a function of stress for each metal and test temperature on log-log plots. Least-square fitted Larson-Miller parameters are shown as functions of stresses.

The effects of abnormal grain growth in molybdenum on creep rates and rupture times are discussed.

Creep of Polycrystalline Alpha and Beta Thallium: *O. D. Sherby*, Stanford University.

The steady state creep rate, in hr^{-1}, for high temperature creep of polycrystalline alpha and beta thallium over a wide range of stress can be accurately expressed by

$$\dot{\epsilon} = 35\,D\,\sigma^{5.2}$$

where D is the self-diffusion rate of thallium in sq cm per hr and σ is the creep stress in kg per sq cm. This empirical formulation coupled with a similar formulation found earlier for alpha and gamma iron suggests that creep of most pure polycrystalline metals at high temperatures is controlled by some type of diffusion process. Recent theories of creep proposed by Weertman and Mott are reviewed and compared with the experimental findings on thallium. It appears that Weertman's theory is to be preferred since it predicts that the creep rate should be proportional to the self-diffusion rate of atoms.

Study of the Influence of Nitrogen on the Creep-Rupture Properties of a Nickel-Chromium Alloy Hardened With Titanium and Aluminum: *R. L. Jones*, Convair-Astronautics, and *J. W. Freeman*, University of Michigan.

A study was made to determine the effect of nitrogen on the creep-rupture properties of a simplified 78 Ni - 19 Cr - 2 Ti - 1 Al alloy subject to precipitation hardening by the γ' phase, Ni_3 (Al, Ti). The study was designed to first determine if nitrogen was beneficial or deleterious to properties, and second, with this established, to study the effects of nitrogen on the structure of the alloy and relate these structural effects to properties.

Heats were prepared in a vacuum induction melting furnace with nitrogen content increasing from 0.003 to 0.034 pct. The influence of nitrogen on the creep-rupture properties was evaluated by tests at 1350°F and 28,000 psi. Structural studies were carried out on samples after heat treatment, using optical and electron microscopy, X-ray diffraction and mechanical property measurements.

It was found that raising the nitrogen from 0.003 to 0.013 pct increased creep resistance by a factor of 3. At the same time, nitrogen up to 0.034 pct increased the resistance to fracture by delaying the initiation of tertiary creep. The increased resistance to creep and fracture resulted in increased rupture life with the most marked effect found from increasing the nitrogen from 0.003 pct (average rupture life 100 hr) to 0.013 pct (average rupture life 500 hr).

Several structural effects indicate that the increased creep resistance was related to the increase of nitrogen in solution prior to creep-rupture testing. The delay in the initiation of tertiary creep was related to the increased time required for the appearance of micro-cracks. The reduction of the rate of tertiary creep and the increase in the duration of tertiary creep was related to the reduction in the number of micro-cracks growing during this period of creep.

WEDNESDAY, FEBRUARY 18, AM

IMD
Research Summaries on Observations of Dislocations

(Based on Submission of Research Abstracts)

9:00 am St. Francis Hotel Colonial Room

A. E. Gorum, Chairman

Fracture of Chemically Polished Magnesium Oxide: *R. J. Stokes, T. L. Johnston*, and *C. H. Li*, Minneapolis-Honeywell Regulator Co.

Magnesium oxide crystals exhibit a wide scatter in ductility when loaded under three-point bending or simple tension. Thus, given a number of crystals cleaved from the same parent, a few may deform considerably (up to 15 pct in the tension surface) while others fracture with no macroscopic deformation whatsoever. This scatter is also observed for specimens which have been chemically polished in fresh, boiling, 85 pct-orthophosphoric acid prior to testing. However, if a polished crystal is immersed in hot acid (~70°C) so that the tension surface is continuously removed during deformation there is *always* considerable ductility before failure. The ductility is similarly enhanced if a crystal is periodically removed from the testing machine and repolished. Under these two latter special conditions it is found that fracture originates from a *linear* source rather than the *surface point* source typical of less ductile material. When the surface is continuously polished the linear source is invariably *inside* the crystal.

Detailed examination of crystals with a polarizing microscope before and after fracture has established that these linear sources are, in fact, produced by the growth of Stroh-cracks. Stroh-cracks are produced as a result of plastic flow and take the form of tiny slits lying along the {100} bending axis. A most surprising feature of recent observations is that these slits can be stable under tensile stress. Indeed crystals with slits actually in the tensions surface have been observed to deform a further 1 pct before catastrophic failure originated from one of them.

The formation and growth of Stroh-cracks are described in detail, and the reason for their stability is discussed.

Ductile-Brittle Transition in Silver Chloride: *T. L. Johnston, R. J. Stokes*, and *C. H. Li*, Minneapolis-Honeywell Regulator Co.

Silver chloride is one of the most ductile of the inorganic solids having the rock salt structure and under uniaxial loading the usual fracture mode is of the shear or fibrous type. We have found however that under impact conditions, in the presence of a notch, silver chloride exhibits brittle behavior at room temperature. The fracture mode under these conditions is predominantly (100) cleavage.

To investigate this phenomenon further, the energy absorbed during impact loading was measured as a function of temperature. High purity single crystals and extruded chemical grade polycrystalline material were used in the form of sub-size notched Charpy specimens.

Both materials exhibited a sharp ductile-brittle transition at ~70°C, i.e. $0.48T_m$ where T_m is the melting point of silver chloride in degrees Kelvin. Above this temperature they adsorbed impact without fracture. Below 70°C, the extruded specimens fractured entirely by cleavage whereas the notched single crystals displayed two distinct fracture modes. In the latter case cracks spread from the notch apex by a ductile shear mechanism before propagating by cleavage. The proportion of shear zone decreased with temperature.

It was further observed that brittleness could be induced in the absence of a notch by lowering the temperature and raising the strain rate. This is shown by the fact that at −196°C unnotched single crystals cleave under impact conditions but can undergo extensive deformation in a slow bend test.

The ductile-brittle transition is clearly a bulk property of silver chloride and is not related to grain boundary embrittlement. Possible reasons for this behavior are discussed.

Plastic Anisotropy of LiF and Other Rocksalt-Type Crystals: *J. J. Gilman*, General Electric Co.

Although many features of dislocations in crystals depend only on the elastic stress fields of the dislocations, some features are dependent on the detailed atomic structures of dislocations. Perhaps the most important feature of a dislocation is its mobility, and the present work is an attempt to demonstrate that the mobilities of dislocations often depend strongly on details of atomic structure. *Plastic anisotropy* is the quantity that was measured for this purpose. Since it is a ratio, this quantity is not sensitive to impurities, perfection, etc., in contrast to most other mechanical parameters of crystals.

The stresses needed to cause <110> dislocations to move on {100} as compared with {110} planes have been measured in torsion tests in LiF and in potassium halide crystals. Glide is much more difficult on {100} planes than on {110} planes in LiF, except for temperatures above about 400°C.

It is shown that the ease of {100} glide increases relative to {110} glide through the series KCl → KBr → K_I and that PbTe prefers to glide on {100} planes. Thus {100} glide seems to be favored by high ionic polarizability as Buerger first suggested.

These results show that the atomic structures at the cores of dislocations play an important role in the behaviors of alkali halide crystals.

Dislocation Theory of Fracture in Metals: *H. Wiedersich*, Westinghouse Electric Corp.

An expression for the energy of a wedge shaped crack (Stroh crack) in a material under an applied tensile stress is developed. The present analysis indicates that the crack will grow catastrophically in general when

$$\sigma n b \geq 4\gamma$$

where

σ = applied tensile stress perpendicular to the long dimension c of the crack
n = number of dislocations forming the crack
b = Burger's vector
γ = surface energy.

The critical length of the crack is only half the length of the corresponding crack size in Griffith's theory. The fracture stress σ depends upon the specific relationship between σ and n, which is not only dependent upon b, γ, and the elastic properties, but as well upon the plastic properties and structural variables. Some possible relations for $n(\sigma)$ will be treated.

IMD Annual Business Meeting

10:45 am St. Francis Hotel Colonial Room

W. J. Harris, Jr., Chairman, Presiding

IMD Annual Lecture

11:00 am St. Francis Hotel Colonial Room

Augustus B. Kinzel and *W. J. Harris, Jr.*, Associate Chairmen

Speaker: *Frederick Seitz*, University of Illinois

Subject: *The Effects of Irradiation Upon Metals*

EMD Annual Stag Luncheon and Business Meeting

12:15 pm St. Francis Hotel Georgian Room

H. H. Kellogg, Chairman, Presiding

Speaker: *Granville S. Borden*, San Francisco.

Subject: *Uncle Sam's Mineral Share Croppers*

WEDNESDAY, FEBRUARY 18, PM

EMD-ISD Applications of the Phase Rule in Extractive Metallurgy

2:00 pm St. Francis Hotel California Room

J. F. Elliott and *W. A. Krivsky*, Associate Chairmen

General Representational Methods for Heterogeneous Ternary Equilibria: *J. H. Downing*, Electro Metallurgical Co., Div. of Union Carbide Corp., and *R. Schuhmann, Jr.*, Purdue University.

Phase Equilibrium Studies Applied to Steel Plant Refractory Problems: *Arnulf Muan*, Pennsylvania State University.

Phase Distribution in the Systems: Iron-Nickel-Lead, Iron-Nickel-Carbon (Saturated) and Iron-Nickel-Lead-Carbon (Saturated): *K. O. Miller* and *J. F. Elliott*, Massachusetts Institute of Technology.

Application of the Phase Rule to the Derivation of Approximate Phase Diagrams Silicon-Oxygen-Carbon: *W. A. Krivsky*, Electro Metallurgical Co., Div. of Union Carbide Corp., and *R. Schuhmann, Jr.*, Purdue University.

A Method for Determination of Solidus Curves in Phase Diagram: *H. Flood*, Norwegian Institute of Technology.

Thermodynamic Properties of Titanium Carbide: *S. Fujisharo* and *N. A. Gokcen*, University of Pennsylvania.

WEDNESDAY, FEBRUARY 18, PM

EMD Rare Earth Metals

2:00 pm St. Francis Hotel Italian Room

F. H. Spedding and *A. H. Daane*, Associate Chairmen

Recent Developments on Production and Extraction of Rare Earth Metals at Ames: *F. H. Spedding* and *A. H. Daane*, Iowa State College.

Electrowinning of Cerium: *Edward Morrice* and *R. G. Knickerbocker*, U. S. Bureau of Mines.

Preparation of Europium and Samarium by Metallic Reduction: *T. T. Campbell* and *F. E. Block*, U. S. Bureau of Mines.

Electrodeposition From Aqueous and Non-Aqueous Solutions: *Therald Moeller*, University of Illinois.

A Compilation of Properties of Rare Earth Metals and Yttrium and Their Compounds: *J. A. Gibson, J. F. Miller*, and *G. W. P. Rengstorff*, Battelle Memorial Institute.

WEDNESDAY, FEBRUARY 18, PM

EMD-MBD Chemical Processes-Nickel

2:00 pm Sheraton-Palace Hotel Comstock Room

John Dasher and *M. E. Wadsworth*, Associate Chairmen

Refining of Nickel-Copper-Cobalt Mattes by Pressure Leaching and Hydrogen Reduction: *R. F. Pearce, J. P. Warner*, and *V. N. Mackiw*, Sherritt-Gordon Mines, Ltd.

Cobalt-Nickel Separation—An Investigation of the De-Merre Process: *D. W. Bridges*, U. S. Bureau of Mines.

Modifications in Nicaro Metallurgy: *Armando Alonso* and *John Daubenspeck*, Nickel Processing Corp., Nicaro, Oriente, Cuba.

Ammonium Sulphate Leaching-Hydrogen Reduction Process for Treating Nicaro Bull-Precipitate: *James Shea*, Battelle Memorial Institute.

WEDNESDAY, FEBRUARY 18, PM

ISD Steelmaking Technology

2:00 pm St. Francis Hotel Olympic Room

W. O. Philbrook and *J. C. Fulton*, Associate Chairmen

Walter Carroll, Discussion Leader

Effect of Rare Earths on Some Stainless Steel Melting Variables: *R. H. Gautschi* and *F. C. Langenberg*, Crucible Steel Co. of America.

Influence of Manganese on P Distribution in Basic Steelmaking Systems: *F. Grandpierre* and *J. F. Elliott*, Massachusetts Institute of Technology.

Interaction of Elements in Liquid Fe: *M. Ohtani*, University of Pennsylvania.

Modified Inland High Temperature Test for Coke, Synthetic Agglomerate and Natural Ores: *Peter Zorena* and *M. O. Holowaty*, Inland Steel Co.

WEDNESDAY, FEBRUARY 18, PM

IMD Symposium on Scale Effects on Properties

2:00 pm St. Francis Hotel Colonial Room

H. W. Paxton and *V. F. Zackay*, Associate Chairmen

A Limited Survey of Scale Effects on Mechanical Properties: *G. T. Horne*, Carnegie Institute of Technology.

A Theory of the Specimen Thickness Effect in Grain Growth: *W. W. Mullins*, Westinghouse Electric Corp.

Effect of Micron Grain Size on Mechanical Properties of Some Steels: *J. C. Shyne, D. J. Schmatz*, and *V. F. Zackay*, Ford Motor Co.

Strength and Dislocations in Whiskers and Microcrystals: *W. W. Webb*, Electro Metallurgical Co., Div. of Union Carbide Corp.

Temperature and Microstructure Dependence of Size Effects in Notched Bend Fracture Tests of Some Alloy Steels: *S. Yukawa*, General Electric Co.

WEDNESDAY, FEBRUARY 18, PM

IMD

Research Summaries on Interfaces and Surfaces (II)

(Based on Submission of Research Abstracts)

2:00 pm St. Francis Hotel Borgia Room

J. Washburn, Chairman

Evaporation of Silver Crystals: *J. P. Hirth* and *G. M. Pound*, Carnegie Institute of Technology.

The flux of evaporation J from {100}, {111}, and {110} planes of silver single crystals and from polycrystalline specimens was measured at 744°C under a high vacuum using a time average weight loss method. Constancy of evaporation rate with time was demonstrated by continuous rate measurements. The evaporation coefficient α was computed from the measured flux and vapor pressure data through the relationship $J = \alpha_{p_e}/\sqrt{2\pi mkT}$. The evaporation coefficients for the close packed planes and the polycrystalline specimens were found to be significantly less than unity. The results are discussed on the basis of current theory of crystals evaporation. The role of lattice imperfections is considered.

Rates of Growth of Proeutectoid Cementite: *R. W. Heckel* and *H. W. Paxton*, Carnegie Institute of Technology.

Diffusion controlled growth of a solute rich precipitate is characterized by the diffusion of the solute in the supersaturated matrix to the surface of the precipitate. The matrix surface concentration is in all cases taken to be that in equilibrium with the precipitate at the temperature of reaction.

On this basis a model of the growth of grain boundary films of proeutectoid cementite has been constructed. The thickness of the films is expressed as a function of the mean concentration of solute in the untransformed matrix.

$$x = 2r_0\left(1 - \sqrt[3]{\frac{C_p - C_i}{C_p - C_m}}\right)$$

where:

x is the thickness of the film
r_0 is the austenite grain radius
C_p is the solute concentration in the precipitate
C_i is the gross composition of the binary alloy
C_m is the mean concentration of solute in the untransformed matrix.

C_m may be calculated from the solution to Fick's Second Law.

$$\frac{\partial c}{\partial t} = D\frac{\partial^2 C}{\partial x^2}$$

Growth data have been obtained experimentally from two hypereutectoid steels.

Wt Pct C	Wt Pct Mn	Wt Pct Si
1.20	0.91	0.23
1.16	<0.001	0.001

Neither steel exhibits cementite films as thick as predicted from the foregoing model. However, the pure binary alloy is characterized by a faster cementite growth rate than that containing manganese and silicon. These results may be explained by an interface controlled growth model accompanied by a build-up of silicon in the austenite at the austenite:cementite interface.

Singular and Non-Singular Interfaces: *K. A. Jackson*, Harvard University.

A criterion which distinguishes between interfaces which are singular (atomically smooth) and those which are non-singular (atomically rough) will be developed. This criterion states that the parameter $\alpha = \frac{L}{kT_E}\cdot\frac{n_p}{n_o}$ is greater than 2 for singular interfaces and less than 2 for non-singular interfaces. In this equation L is the latent heat associated with the transformation, T_E is the equilibrium temperature between the two phases at the interface, k is Boltzmann's constant, n_o is the total number of nearest neighbors in the solid, and n_p is the number of nearest neighbors which lie in a plane parallel to the interface. Surface nucleation is necessary for growth on singular interfaces, resulting in slow growth rates. The formation of new layers is relatively easy on a non-singular interface, leading to rapid growth rates. In the latter case, growth is frequently limited by some factor other than the formation of new layers, such as the rate of dissipation of latent heat. The observed growth forms of various materials will be discussed with reference to the values of the parameter α.

Considerations of Surface Equilibria: *J. E. McNutt, G. M. Andes*, and *J. J. Cox*, E. I. du Pont de Nemours and Co., Inc.

Several well-known expressions are commonly used to relate the geometrical configurations developed at equilibrium intersections of interphase surfaces to the specific free energies of the surfaces. Among these expressions is, for instance, the relationship between the contact angle and the energies of three surfaces meeting along a line. A review is given here of the concepts of surfaces and surface energies involved in deriving and using these relationships. Confusion about these concepts, evident in some recent literature, is discussed.

Liquid-Solid Interfacial Energy in Binary Alloys: *H. W. Weart* and *M. J. Fraser*, Westinghouse Electric Corp.

The free energy of liquid-solid interfaces is an important parameter in the description of such phenomena as nucleation of crystals from liquid solutions, corrosion by liquid metals and metals joining. Aside from some estimates of the magnitude of the energy, however, little is known quantitatively about the effect of such variables as bulk composition of the phases, adsorption, and nature of the exposed solid surface. In the first part of this paper, the available experimental data on liquid-solid interfacial energy are collected and discussed in terms of various empirical correlations which have appeared in the literature. Also included in this section is a discussion of the techniques usually employed for measuring liquid-solid energies in metallic systems.

The second part of the paper presents the results of an experimental study undertaken to determine the effect of bulk composition of the phases on the γ_{LS}/γ_{SV} ratio, where γ_{LS} is the liquid-solid and γ_{SV} the solid-vapor interfacial free energy. The results obtained by application of the sessile drop technique are presented and discussed.

Effect of Oxide Microstructure on the Oxidation Kinetics of Cu-Ni-Mg Alloys: *J. A. Sartell, S. H. Bendel*, and *C. H. Li*, Minneapolis-Honeywell Regulator Co.

Additions of (up to 1 pct) Mg to a 62Cu-38Ni alloy have been found to reduce the oxidation rates drastically in the temperature range from 500 to 850°C. The protective effect was especially marked below 700°C and could be directly related to the microstructure of the oxide layer.

Microscopic examination of the oxide layer disclosed the presence of a network of NiO along the former alloy grain boundaries. This network penetrated the underlying alloy. The grains themselves were oxidized in a manner similar to that observed for the 62Cu-38Ni alloy, containing additional NiO in the form of particles which were dispersed in a matrix of Cu_2O.

It is thought that the protective effect obtained through the addition of Mg to this alloy is due to the formation of the continuous network of NiO which acts as a barrier to diffusion. This network is considered to arise from the segregation of Mg at the alloy grain boundaries. Since Mg is more active than either Cu or Ni, oxidation is more rapid in these regions. In order to test this proposal Cu-Ni-Mg alloy specimens were given a high-temperature homogenizing anneal, quenched, and then oxidized. Oxidation proceeded at about the same rate as for the parent 62Cu-38Ni alloy and no NiO network was formed.

Mechanism for the Oxidation of Cu-Rich Cu-Ni Alloys: *J. A. Sartell* and *C. H. Li*, Minneapolis-Honeywell Regulator Co.

Although a theory for the oxidation of Cu-Ni alloys has been proposed, kinetic data for dilute alloys are incomplete and oxide microstructure and ion movement have not been investigated. Studies have been made in the temperature range from 660 to 882°C for alloys with compositions from 0 to 5 pct Ni. Alloys were prepared by vacuum melting copper and nickel of 99.999 pct purity.

Gravimetric data show that the addition of nickel decreases the oxidation rates to a minimum at about 1 pct Ni, beyond which they increase, eventually exceeding those for pure copper. The location of the minimum appears to be a function of temperature, shifting toward higher nickel contents at lower temperatures.

For the 95Cu-5Ni alloy, inert markers are found quite near the Cu_2O-CuO interface indicating that anion diffusion is predominant. With decreasing nickel content, the marker position approaches the metal/oxide interface; for pure copper it is located at the metal surface, indicating that the anion transport has dropped to zero. The change in marker position seems to indicate that the minimum in oxidation rates is associated with the switch from anion to cation diffusion as the rate determining factor. It appears, therefore, that at compositions above that associated with the minimum rate constant, oxidation occurs by an internal oxidation mechanism while below this value oxidation proceeds in a manner similar to that of pure copper.

The oxide microstructure is consistent with this proposed mechanism. When anion diffusion is the controlling process there is always a zone of internal oxidation which consists of NiO particles embedded in the alloy. In the neighboring oxide scale particles of NiO are dispersed in the Cu_2O. The outer layer consists of CuO. When cation diffusion is the controlling mechanism the oxide layer consists almost entirely of Cu_2O.

Orientation Sensitivity of Alpha Titanium to Electrostaining: *R. H. Hiltz*, Thompson Ramo Wooldridge Inc., and *R. W. Douglass*, Battelle Memorial Institute.

Large grain specimens of iodide titanium prepared metallographically, were stain etched using the technique of New York University as modified by Watertown Arsenal laboratories. Orientations of grains showing an abnormal response to stain etching were determined by back reflection X-ray techniques. X-ray results showed that alpha titanium grains, oriented such that their basal planes were parallel to the polished surface, have a slower reactivity to strain etching than any other orientation. Grains oriented such that their basal planes made small angles with the polished surface exhibited reaction rates between that of the true basal orientation and the normal rate. As the angle with the surface increases the reactivity increases up to a maximum angle of 14°. Basal planes making an angle with the surface of greater than 14° show normal reactivity to strain etching. These data, plus work on polycrystalline specimens, indicate that the oxidation rate of titanium might be reduced by correct alignment of crystal planes.

Nucleation Rate of Cobalt From Dilute Cobalt-Copper Alloys: *J. W. Cahn*, General Electric Co.

The precipitation of cobalt from dilute cobalt-copper alloys can result in an extremely large number (more than 10^{15} per cu cm) of approximately spherical cobalt particles. This number is so large that it rules out most nucleation catalysts, and is by itself a strong argument for believing that the nucleation occurs homogeneously. The present study was undertaken in order to learn more about the nucleation process.

A series of high purity alloys were homogenized and then quenched directly into lead pots at the precipitation temperatures. Magnetic measurements were used to reveal the number of particles as well as their size and shape. It was found that the nucleation rate was neither affected by impurities nor by the temperature of the samples prior to quenching into the lead. From these observations it may be concluded that the nucleation is indeed homogeneous.

The effect of composition and temperature of precipitation was followed for 4 alloys from 0.4 to 2 pct Co and for a temperature range from 400 to 750°C. The nucleation rates and the final number of cobalt particles formed varied over many orders of magnitude in this interval and are compared with existing nucleation theories.

Grain-Boundary Energies in Gold-Copper Alloys: *J. E. Hilliard*, General Electric Co., *Morris Cohen*, and *B. L. Averbach*, Massachusetts Institute of Technology.

The ratio of grain-boundary energy to surface energy in the gold-copper system has been determined as a function of composition. The effect of orientation was not studied, the measurements being confined to high-angle boundaries.

The relative boundary energy was estimated from interferometric measurements of the groove angle of grain boundaries at the surface of specimens thermally etched in vacuum at 850°C. Some of the measurements were made on a modified Bausch and Lomb metallograph and the remainder on a Zeiss interference microscope. About twenty observations were made on each alloy. Most of the grooves examined had a parabolic profile as predicted by Mullins.

The average values for the ratio: grain-boundary energy/surface energy are: 0.33, 0.34, 0.38, 0.31, 0.25, and 0.22 at., respectively, 0, 20, 40, 60, 80, and 100 at. pct Au. Using the recent data of White, Adams, and Wulff for the surface energies, these ratios yield the following values of the absolute grain-boundary energies: 540, 390, 350, 280, 290, and 340 erg cm^{-2}.

Precipitation Processes in Mg-Th-Zr Alloys: *Lorenzo Sturkey*, The Dow Chemical Co.

The rates of precipitation of Mg-Th compounds in a Mg-3.3Th-0.54Zr (HK31A) have been studied at temperatures from 600 to 700°F. Aging the completely solution-treated alloy precipitates both the equilibrium Mg-Th compound, of probable composition Mg_3Th, and a transition phase coherent with the matrix. The transition phase gradually transforms into the equilibrium compound, but an increase in temperature increases its rate of formation more than its rate of transformation.

Quantitative X-ray spectrometer results from aged material, both as-cast and cold-rolled samples, show that the fraction f of the available thorium precipitated may be described by:

$$f = 1 - e^{-(t/\tau)^{1/2}}$$

At 635°F: τ (as-cast) = 31 hr, τ (30 pct cold-roll) = 4.5 hr.

At 700°F: τ (as-cast) = 4.4 hr, τ (30 pct cold-roll) = 0.67 hr.

Temperature changes have little effect on nucleation, and the increase in precipitation after cold rolling may be attributed to an increase in the number of precipitation nuclei. Since nucleation is apparently not an important factor, an *activation energy* for the diffusion of Th in Mg may be calculated to be 40-45 kcal per mole.

Electron diffraction patterns from the transition phase show that it is primarily cubic, a_0 = 8.57 A, with the Cu_2Mg, Laves-phase structure. One of the {111} planes of this compound grows parallel to the basal plane of the magnesium matrix, and considerable stacking disorder occurs parallel to this plane.

THURSDAY, FEBRUARY 19, AM

IMD

Symposium on Alloy Strengthening at Elevated Temperatures

Part I—Solute and Impurity Effects

9:00 am St. Francis Hotel California Room

Allan Lawley and *W. D. Robertson*, Associate Chairmen

Effect of Alloying on Grain Boundary Deformation at Elevated Temperature: *J. Intrater* and *S. Weinig*, Materials Research Corp.

Measurements by McLean of the contribution of the grain boundaries to the creep strain have shown that the grain boundary sliding accounts for less than 10 pct of the total elongation. New results, however, indicate that grain boundary sliding per se, di-

rectly effects the creep elongation and fracture characteristics. In fact, a linear relationship has been shown to exist between the grain boundary and the total creep strain. It has been shown that void formation which leads to fracture is caused by grain boundary sliding. Here again, a linear relationship between the amount of sliding and the number of voids in the boundary has been found.

Many theories have been proposed for grain boundary sliding. In a study of grain boundary sliding in bi-crystal specimens, it was found that not only was grain boundary *zone shearing* as suggested by Rhines et al operative, but a different mechanism was also observed. The latter mechanism occurred without any plastic deformation of the zone immediately adjacent to the boundary. It constituted *pure* grain boundary sliding.

It was established that void formation at the boundaries occurred due to the development of tensile stresses at the jogs. The mechanism proposed for pure grain boundary sliding is as follows: Upon the application of a load, stress relaxation occurs in the interjog section. When the interjog length is sufficiently long, the stress at the jog exceeds the fracture strength of the material and rupture at the jog occurs creating a void. Sliding is then propagated catastrophically along the whole length of the boundary. Two effects are therefore occurring; sliding in the interjog section and local migration of the boundary. Both effects are interrelated.

In the event that interjog sliding is the rate controlling process, then the effect of impurities will be to increase the sliding resistance by converting disordered regions at the boundary into more orderly regions.

If local grain boundary migration (elimination of jogs) is necessary for continuous grain boundary sliding and is rate controlling, then the effect of impurities will be to decrease the rate of migration; and therefore, effectively prevent the interjog distance from increasing.

A series of experiments on polycrystalline specimens were performed in which internal friction measurements were used to determine the solute adsorption and then corrboratory creep tests were made on specimens of similar solute content.

It was found that the greater the adsorption of the specific element, the less was the contribution to the over-all creep strain. It was further found that by increasing the total solute adsorption, using alloying elements of both positive and negative size factor, the grain boundary contribution to the creep strain was almost negligible.

The data obtained from both internal friction techniques and the directly read creep contributions of the grain boundary as a function of solute adsorption substantiated the predicted alloying effects but does not determine which is the rate controlling process. It is the belief of the authors based upon theoretical consideration that the rate controlling process is that of local grain boundary migration.

Strain Aging During Creep of Armco Iron: *J. Sward*, The Elliott Co., Div. of Carrier Corp., and *H. Conrad*, Westinghouse Electric Corp.

To investigate the effect of strain-aging on incremental-loading creep tests were conducted on Armco iron in the temperature range of 25 to 225°C. For stresses below the yield stress, microcreep occurred. When the stress reached the yield stress, macrocreep occurred after a delay time. The macrocreep curves were characterized by a sudden large flow followed by a rapidly decreasing creep rate, so that creep practically ceased after a period of 1-2 min at 25°C or after a period of less than 5 sec at 75°C and higher temperatures. Once macrocreep stopped, several stress increments were required to again initiate flow, indicating that the dislocations had become locked. The number of stress increments required for unlocking increased with increase in temperature from 25 to 75°C but remained essentially constant for higher temperatures. Further, the number of increments required for unlocking was relatively insensitive to the total amount of previous strain. An evaluation of the data indicated that the locking of dislocations is due to the ordering of solute interstitials in the stress field of a dislocation.

Strength, Stability, and the Equicohesive Point: *E. E. Underwood*, Battelle Memorial Institute.

Solid Solution and Two-Phase Strengthening in Ni-Cr, Ni-Mo, and Ni-W Alloys at High Temperatures: *Regis Pelloux* and *N. J. Grant*, Massachusetts Institute of Technology.

The effects of solid solution alloying and of a second phase on the creep rupture properties and deformation mechanisms of pure nickel were studied by means of creep rupture tests on binary alloys of nickel-chromium (19.59-29.3-35.8-40.12-44.95 wt pct Cr), nickel-molybdenum (10.2-15.0-20.3-23.2-25.5-27.3 wt pct Mo) and nickel-tungsten (20-28-30.5-35.1-39.9 wt pct W) at 1200 and 1500°F.

The mechanical properties of the solid solution alloys were determined at room temperature in order to have a basis of comparison of the strengthening effects. The room temperature flow stress and ultimate tensile strength of the solid solution alloys increases in the order of chromium, molybdenum, and tungsten for the same content (at. pct) of solute element. At 1200 and 1500°F, for solute content less than 10 at. pct, the stress for rupture in 1 and 100 hr increases in the order of chromium, molybdenum, and tungsten, in the same manner as the flow stress at room temperature. For higher solute content the maximum strength of the solid solution alloys is obtained for the alloys which were saturated with solute element. For these alloys the strength increases in the order of tungsten, molybdenum, chromium, i.e., the higher the solute content at the limit of solubility, the greater the strength of the alloy.

The effects of the second phase on the high temperature strength of the alloys are strongly dependent on the nature and dispersion of the second phase. The two-phase alloys were overaged past peak hardness prior to testing. At 1200°F the second phases $MoNi_4$ and WNi_4 contribute to an effective strengthening of the saturated solid solutions for short and long rupture life, while at 1500°F where diffusion rates are faster, significant strengthening due to the second phase occurs only in long time rupture tests. In the case of the nickel-chromium system, the second phase, a chromium rich solid solution, causes a decrease in the strength of the saturated nickel rich solid solutions.

All fractures are intercrystalline in the longer time tests. The two-phase alloys invariably exhibit low ductility whereas the solid solution alloys showed a ductility which decreased in the order chromium, molybdenum, and tungsten.

The comparison of strength, ductility, fracture behavior, and forgeability, of the alloys tested leads to some criteria for the design of simple high temperature alloys.

On the Deformation Characteristics of Certain Dilute Copper-Base Solid Solution Alloys: *N. G. Ainslie*, *R. W. Guard*, and *W. R. Hibbard, Jr.*, General Electric Co.

It has frequently been proposed that solid solution strengthening in face-centered cubic alloys raises the yield strength but has little effect on the flow curve in general. The effect of different solutes is related to the effects of size difference, valance difference and similar variables on the yield stress. Evidence is presented that copper-base solid solutions with different solutes having equal grain sizes, no preferred crystallographic orientation, equal electron-atom ratios, and, within experimental scatter, identical initial yield strengths need not have identical stress-strain curves at strains larger than about 0.04. The stress-strain behavior is rationalized in terms of the chemical interaction between solute atoms and extended dislocations proposed by Suzuki and the mobility of dislocations using what is thought to be a somewhat different means of representing stress-strain data.

The implications of this model with respect to the effect at elevated temperatures is discussed.

THURSDAY, FEBRUARY 19, AM

IMD

Research Summaries on Interfaces and Surfaces (III)

(Based on Submission of Research Abstracts)

9:00 am St. Francis Hotel Borgia Room

O. D. Sherby, Chairman

Evaporation of Dilute Liquid Iron Alloys: *F. W. Kuether*, Minneapolis-Honeywell Regulator Co.

The evaporation of C, Co, Ni, Al, Cr, Cu, Mn, Si, and Sn from liquid iron have been measured at 1560 ± 25°C in vacuum. Dilute binary liquid alloys were obtained by adding small known amounts of the solute element to a 30 gm melt of high purity iron. Collection of the vapor started as soon as the addition was made and continued for a fixed period of time after which the power source was removed. Due to its small heat capacity the ingot cooled down to 1000°C in 30 sec and evaporation virtually ceased. Both the condensed vapor and the solidified alloy were chemically analyzed for the solute element.

Differences in the vapor pressure of the solute elements, when present in the liquid alloy, and the iron produced an increase or decrease in solute concentration. Only carbon of the above elements became progressively enriched during evaporation. The remainder, with the exception of cobalt and nickel, evaporated much more rapidly than iron and were correspondingly depleted. Cobalt and nickel evaporated at nearly the same rate as iron. The rate of evaporation of a particular solute element depends upon its concentration. For a rapidly evaporating solute element, if this dependence is assumed linear then the atomic percentage changes exponentially with time of evaporation. For all solute elements studied here, the time constant for the exponential decrease, when corrected for crucible geometry and temperature, was in quantitative agreement with that predicted by Raoult's law. If several of the above elements were present at the same time, each evaporated at the same rate as if it were a simple binary alloy. Raoult's law can be applied therefore to compute the purification accomplished after ½ of the iron atoms have evaporated.

Vapor Pressure Studies of Nickel and the Alloys 5 Al-95 Ni, 20 Cr-80 Ni, and 4 Al-17 Cr-79 Ni: *E. A. Gulbransen* and *K. F. Andrew*, Westinghouse Electric Corp.

Vapor pressure studies were made using the Langmuir evaporation method on pure nickel and the alloys 5 Al - 95 Ni, 20 Cr - 80 Ni and 4 Al - 17 Cr - 79 Ni. The results for nickel gave a heat of sublimation ΔH°_0 of 103.5 ± 0.2 kcal per gm atom at 0°K. The vapor pressures were lower than those previously reported.

Vapor pressures on the 20 Cr - 80 Ni alloy nearly followed Henry's law, while the 5 Al - 95 Ni alloy showed negative deviations from Henry's law. The ternary alloy 4 Al - 17 Cr - 79 Ni show positive deviations from Henry's law and higher vapor pressures than the 20 Cr - 80 Ni alloy.

Oxidized samples of nickel and the several alloys were also studied. Thick and thin oxide films had little effect on the vapor pressure curve of nickel. A small effect for the oxide film was noted on the 20 Cr - 80 Ni alloy. Studies on the 4 Al - 17 Cr - 79 Ni alloys showed the oxide films to lower the vapor pressures of the alloy by a factor of 10.

The role of vapor pressure in oxidation processes was briefly discussed.

Vapor Pressure Studies of Iron and Chromium and the Alloys 5.4 Al-94.6 Fe, 21.9 Cr-78.1 Fe, and 4.8 Al-21.5 Cr-73.7 Fe: *E. A. Gulbransen* and *K. F. Andrew*, Westinghouse Electric Corp.

Vapor pressure measurements were made on iron, chromium, and the alloys 5.4 Al - 94. 6 Fe, 21.9 Cr - 78.1 Fe, and 4.8 Al - 21.5 Cr - 73.7 Fe to aid in interpretation of the mechanism of oxidation of the heat resistant alloy 4.8 Al - 21.5 Cr - 73.7 Fe. The addition of 5.4 wt pct Al to iron lowered the vapor pressure by 50 pct while the addition of 21.9 wt pct Cr increased the vapor pressure. The 4.8 Al - 21.5 Cr - 73.7 Fe alloy gave a vapor pressure curve close to that for pure iron. Aluminum appears to lower the vapor pressure of both iron and chromium in high temperature alloys.

Oxide films formed on the chromium-iron alloy had only a small effect on the vapor pressure of chromium and iron from the alloy. However, oxide films on the alloys containing aluminum reduced the vapor pressures by a factor of ten.

The high heat resistance of the aluminum-chromium-iron alloys is partly due to the action of aluminum in lowering the vapor pressures of iron and chromium in the alloy and to the fact that the oxide film further lowers the vapor pressure of iron and chromium by limiting diffusion of the metal ions to the surface.

Grain Growth in Silicon Iron: *P. K. Koh*, Allegheny Ludlum Steel Corp.

Isothermal salt bath annealing of cold rolled 3 pct Si-Fe sheet was conducted at temperatures ranging from 927 to 1260°C in order to investigate the grain growth behavior. Within the temperature range studied, normal grain growth did not take place, instead nucleated grain growth prevailed. In the same temperature range the final grain size was found to decrease with increasing annealing temperature. Low temperature isothermal annealing produces a strong (110) [001] texture, while high temperature annealing produces a considerably weaker texture of essentially (110) [001] type orientations. For the time-temperature study of the grain growth, use was made of the magnetic torque test to obtain fractional texture changes. Families of sigmoidal curves were observed.

The decrease in grain size with annealing temperature could be explained by a decrease in the G/N ratio in the manner discussed by May and Turnbull in connection with impurity effects at various annealing temperatures. The present results also confirm the suggestion by May and Turnbull that the decrease in texture with increasing annealing temperature is due to the growth of grains deviating widely from the (100) [001] orientation which they called a micro-secondary recrystallization process.

Kinetics and Mechanism of Dissolution of Copper in Ferric Chloride Solutions: *H. M. Ferrari*, Westinghouse Electric Corp., and *M. J. Sinnott*, University of Michigan.

The reaction between copper and ferric chloride has been of considerable industrial importance for many years. It has been used primarily in the photoengraving industry to produce plates to be used in the printing processes. In recent years the process has been used to produce printed circuits in the electronics and electrical industries. While considerable industrial utilization has been made of this process, the many variables associated with the process have not been adequately investigated in order to determine the mechanisms that are operating. In the present investigation the kinetics of dissolution of copper in ferric chloride solutions were studied as a function of solution and metallic variables.

Data on the dissolution rates of copper single crystals as a function of the ferric chloride concentration; the ion contents of chloride, ferric, cupric, ferrous and hydrogen; the dissolved oxygen content; and the metallic variables, crystallographic orientation and surface finish were obtained. Mechanisms describing the reactions which are in agreement with the kinetic data are presented. The reaction is a diffusion controlled process at temperatures above 7°C and is independent of the metallic variables and controlled by the rate at which complex ions diffuse to the copper surface and by the rates at which chloride ions diffuse to a cuprous oxide film. At temperatures below 7°C the process is chemically controlled and the dissolution rate is a function of the orientation of the copper crystals.

Phase Relations and Precipitation in Cobalt-Titanium Alloys: *R. W. Fountain* and *W. D. Forgeng*, Electro Metallurgical Co., Div. of Union Carbide Corp.

Cobalt-titanium alloys containing 3 to 30 pct Ti have been studied by metallographic, X-ray diffraction, hardness, and electrical resistivity methods. As a result of this investigation, a modified cobalt-titanium equilibrium diagram has been constructed. The principal modifications are:

1. The existence of a new intermediate phase, γ, with a FCC crystal structure and ranging in composition from about 17.0 to 21.7 pct Ti at temperatures below 1000°C. The lattice parameter of this phase varies from 3.604 to 3.613A with increasing titanium content.
2. The formation of γ by a peritectic reaction between β cobalt solid solution and liquid at about 1200°C. At the peritectic temperature, the γ phase contains about 14 pct Ti.
3. A eutectic between the intermetallic compound, Co_2Ti, and the γ phase, rather than cobalt-rich solid solution, and a higher eutectic temperature than previously reported (~1170°C).
4. A solid solubility of less than 3 pct Ti in cobalt at temperatures below 700°C.

Changes in hardness upon precipitation of the γ phase in alloys containing 3, 6, and 9 pct Ti were found to be associated with an initial rapid increase in hardness followed by a plateau and then a second, more pronounced hardness increase. Electrical resistivity measurements suggested that two different kinetic processes were involved in this behavior. The first stage which takes place in very short time periods is characterized by a large value for the time exponent which suggests that the precipitate has the form of very thin plates. With further aging, the value of the time exponent decreases almost discontinuously to a lower value, suggestive of early impingement during the growth of the precipitate particles.

Oxidation of Tin: *C. Luner*, U. S. Steel Corp.

The oxidation kinetics of tin have been studied over a range of temperatures from 168 to 211°C and oxygen pressure from 4 to 10 mm Hg using a manometric method. The oxide formed was identified as α-SnO by electron diffraction.

Reproducible rate curves were obtained when the tin samples were pretreated by degreasing and air drying. However, when the tin surface was pre-treated by abrasion under alcohol with alumina, reproducibility was not obtained. Microscopic examination revealed that the alumina was embedded in the tin surface. These results point out the importance of surface treatment in the study of the oxidation of metals, especially where the metal is soft and the abrasive can be embedded in the surface.

The kinetics were found to follow a logarithmic equation, $\frac{dw}{dt} = ae^{-\alpha w}$, where w is the oxygen consumed per sq cm, α and a are constants. The integrated form of this equation can be written

$$w = \frac{1}{\alpha}(\ln(t + t_0) - \ln t_0)$$

with $t_0 = \frac{1}{\alpha a}$. The constants α and t_0 were evaluated and used to calculate a, which is the initial rate when $t = 0$. The calculated rates were in close agreement with those obtained experimentally.

An apparent activation energy of 23.3 Kcal per mole was obtained from the temperature dependence on the initial rate.

Possible mechanisms for the oxidation are discussed.

Surface Energy Effects in the Mechanical Properties of Solids: *S. Floreen, E. E. Hucke,* and *D. V. Ragone,* University of Michigan.

A number of investigations have shown that surface environment may have a significant effect in the deformation of solids. At the present time no complete theory has been evolved which satisfactorily accounts for these effects.

It would appear that a general theory can be evolved which predicts the effect of environment. This theory is based on surface energy, and the change in surface energy with strain. Theoretical treatments by Herring and Shuttleworth have shown that the surface energy of a solid should vary with strain. If this is true, many of the observed phenomena can be explained on a surface energy basis. In particular, the change in elastic modulus, the change in ductility and fracture strength, the strength of metal whiskers, hot tearing, and stress corrosion as a function of environment may well be explained on this basis.

This generalized theory does not necessarily disagree with the current explanations offered for the effect of environment. Both Herring and Van der Merwe have shown that the surface energy may be considered in terms of dislocation theory. Thus surface energy considerations could be applied to the dislocation theories of solids. In the same manner surface energy considerations could also be applied to the theory that environment effects are caused by micro cracks at the surface.

Interface Compositions in Multi-Phase Cu-Zn Diffusion Couples: *Victor Macres,* Stanford University, *J. T. Norton,* and *R. E. Ogilvie,* Massachusetts Institute of Technology.

The compositional gradients and interface compositions in multiphase Cu-Zn diffusion couples were studied to determine the agreement between those observed and what one would expect from the equilibrium phase diagram.

Copper-zinc, alpha brass-zinc, and beta brass-zinc couples were prepared and diffused at 400°C for 2.0, 4.6, 9.6, 17.2, 26.1, 50, 102, and 169 hr. Two phase alloys of beta-gamma, gamma-epsilon and epsilon-eta were also prepared and equilibrated at 400°C.

The compositional gradients and compositions of the individual grains in the two phase alloys were measured with an electron microbeam probe. The probe size is about 2 μ in diam.

It is concluded that the interface compositions remain constant with diffusion time and that the interface compositions are those expected from the phase diagram.

Of particular interest is the results of the Matano analysis on the gamma phase. At 34 pct Cu the diffusion coefficient is seventy times greater than at 40 pct Cu. This can be explained on the basis of a defect lattice developing in the zinc region.

Effect of Elastic Strain on the Electrode Potential of Metals: *Ling Yang, G. T. Horne,* and *G. M. Pound,* Carnegie Institute of Technology.

Some of the more careful measurements of the electrode potential of uniaxially stressed pure metals show that tension makes the metal more noble while compression makes it less noble. The magnitude of the potential shift is of the order of several tenths of a millivolt per 1000 psi. These results contradict the classical theory of Gibbs which shows that the chemical potential has properties of a tensor and predicts that either uniaxial tension or compression should make the metal less noble by several microvolts per 1000 psi.

In the present work it is shown that choice of a different set of physical constraints for transport of atoms leads to a chemical potential that is not of a tensorial nature and predicts electrode potentials in good agreement with observation. The plausibility of these non-Gibbsian constraints in electrochemical processes is discussed.

Phase Relations in the Ti-Al System: *Elmars Ence* and *Harold Margolin,* New York University.

Several investigations have raised questions as to the validity of the published version of the Ti-Al System. The present work, dealing with the portion of the diagram up to 16 pct Al and below the melting point, has revealed, in addition to α and β, the existence of two phases, δ and γ by both metallographic and X-ray examination. The solubility of aluminum in beta titanium is quite extensive, going beyond the limits reported here. The position of the $\beta/\beta + X$ boundary is approximately the same as reported by earlier investigators for the $\beta/\alpha + \beta$ boundary. The solubility of Al in α is restricted and at 800°C is approximately 8 pct.

Alpha forms peritectoidally by the reaction $\beta + \delta \rightarrow \alpha$ in the vicinity of 1075°C. The δ-phase occurs in the composition region 9-16 pct Al and forms by the peritectoid reaction $\beta + \gamma \rightarrow \delta$ in the vicinity of 1150°C. The structure of δ is believed to be hexagonal and the phase is unstable, transforming to δ^1, similar in structure to α-titanium.

The gamma phase, previously indicated as Ti_2Al, has been reported by the authors as having a hexagonal structure with c/a approximately ½ that of α-titanium.

THURSDAY, FEBRUARY 19, AM

ISD Basic Science of Steelmaking

9:00 am St. Francis Hotel Georgian Room

N. A. Gokcen and *C. W. Sherman,* Associate Chairmen

Kinetics in the Reduction of Silica From Blast Furnace Type Slags: *J. C. Fulton,* Allegheny Ludlum Steel Corp., and *John Chipman,* Massachusetts Institute of Technology.

Some Thermodynamic Properties of Si_3N_4: *R. Pohlke* and *J. F. Elliott,* Massachusetts Institute of Technology.

Activities of CaO, Al_2O_3, and SiO_2 in $CaO\text{-}Al_2O_3\text{-}SiO_2$ Slags: *F. C. Langenberg,* Crucible Steel Co. of America, and *John Chipman,* Massachusetts Institute of Technology.

Kinetics of Vacuum Induction Refining-Theory: *E. S. Machlin,* Utica Metals.

THURSDAY, FEBRUARY 19, AM

EMD Refractories

9:00 am St. Francis Hotel Italian Room

J. A. Pask and *A. E. Fitzgerald,* Associate Chairmen

Selection of Refractories for Lead Reverberatory Furnaces: *O. M. Wicken,* Harbison-Walker Refractories Co.

Extension of Nonferrous Metallurgy Techniques Through Full Use of Properties of Super Refractories: *R. W. Brown,* The Carborundum Co.

Problems Unique to the Secondary Aluminum Industry: *W. H. Stewart,* H. K. Porter Co.

Cermets-Current Types and Applications: *T. J. Planje,* Missouri School of Mines.

THURSDAY, FEBRUARY 19, AM

EMD Chlorination Processes (I)

9:00 am St. Francis Hotel Colonial Room

R. M. Horning and *L. W. Coffer,* Associate Chairmen

Process Development Program for Chlorination of Oxide Ores: *J. F. Heiss,* Stauffer Chemical Co.

The development of a typical metal chlorides process from the laboratory stage through large-scale pilot plant testing will be discussed. Flow sheets showing alternative processes for manufacturing metal chlorides will be presented. Information which should be collected during the development program in order to properly design the commercial plant will be outlined. Factors to be considered in process equipment selection will be listed. Benefits of large-scale piloting of a metal chlorides operation will be discussed.

Pellet Bed Chlorination of Zirconium Oxide: *A. T. McCord*, Carborundum Metals Co.

Pilot plant production of ZrO_2 pellet feed material and the development of a chlorinator in which to chlorinate this type of feed material will be discussed. Intimacy of mixing of the components in the pellet and complete utilization of chlorine will be emphasized.

Preparation of Zirconium in a Continuous Ram Reactor: *W. W. Dunham, Jr.* and *R. D. Toomey*, National Lead Co.

A pilot plant process for the production of reactor-grade zirconium ingots is described. The process includes a continuous reduction step, wherein $ZrCl_4$ is reduced to metal and then consolidated and extruded in dense compact form. With no further processing, the compact is arc melted as a consumable electrode to ingot of exceptionally high purity.

A review of the principles involved, quality data, and the commercial potential of the process is presented.

Anhydrous Chromic Chloride Production by Chlorination: *T. S. Perrin, R. L. Annis, R. G. Banner, F. S. Mahne*, and *J. Kourilo*, Diamond Alkali Co.

High temperature chlorination of chromic oxide to produce pure anhydrous chromic chloride by a practical process has been achieved. A pilot plant capable of producing 50 lb of $CrCl_3$ per hour is in operation. Work is underway for chlorinating other chromium bearing materials.

EMD

First Extractive Metallurgy Division Lecture

11:00 am St. Francis Hotel Colonial Room

H. H. Kellogg, Chairman

Speaker: *W. J. Kroll*, Consulting Metallurgist.

Subject: *The Present State of Titanium Metallurgy.*

THURSDAY, FEBRUARY 19, PM

IMD

Symposium on Alloy Strengthening at Elevated Temperatures

Part II—Dispersion and Precipitation Effects

2:00 pm St. Francis Hotel California Room

James Poynter and *G. M. Ault*, Associate Chairmen

Solute and Precipitation Effects on the High-Temperature Strength of Ni-Ti Alloys at Elevated Temperatures: *R. W. Guard*, General Electric Co.

The nature of the creep curves at elevated temperatures from 1200-1500°F are examined for a number of different compositions across the Ni-Ti binary from 0-6.4 A/O Ti. The variation of creep strength and the effects of alloying (both single phase and two phase) on the shape of the creep curve and the temperature and stress dependence of the creep rate are described for the alloys.

The results are discussed on the basis of presently available theories of solute and precipitate effects. It is demonstrated that a solute strengthening persists at temperatures above that expected from the usual atmosphere model. The measurements of temperature dependence of the strength do not indicate any change of the optimum particle size from fine to coarse within the temperature region studies.

Iron-Alumina Materials: *A. Gatti*, General Electric Co.

Role of Oxygen and Nitrogen in Vacuum and Air Melting of a Complex Heat-Resistant Alloy: *R. F. Decker*, The International Nickel Co., Inc., *J. P. Rowe*, and *J. W. Freeman*, University of Michigan.

The relative hot workability and the creep-rupture properties at 1600°F of a 55Ni-20Cr-15Co-4Mo-3Ti-3Al alloy were evaluated for laboratory vacuum-induction, vacuum-arc, and air-induction melting. The main emphasis was placed on the role of oxygen and nitrogen. The effects of these elements was studied when they were added after vacuum melting as well as when they were derived through the melting method. Because trace amounts of boron and zirconium were known to markedly improve both hot workability and creep rupture properties, the investigation included these elements as variables.

The level of boron and/or zirconium was far more influential on the properties than the melting method. Vacuum melting, however, had the following advantages:

1. Corner cracking was reduced and bar surface improved during hot rolling.
2. Creep-rupture properties were more uniform within a heat.
3. Creep-rupture properties were somewhat superior at low boron plus zirconium heats and in heats with only zirconium. Air heats were, however, superior at high levels of boron plus zirconium.
4. The oxide and carbo-nitride inclusions were fewer.
5. Phosphorus level was reduced although property changes could not be related to this effect.

Oxygen or nitrogen added alone to heats after vacuum melting had practically no effect on creep-rupture properties. They did increase the number of oxides or carbonitrides in the structure.

Exposure to air after vacuum melting resulted in higher ductility in the rupture test than was obtained by any other melting condition. This suggests that these elements are beneficial to ductility and that vacuum melting does remove unidentified elements detrimental to ductility. The susceptibility to corner cracking during hot rolling was increased over vacuum melting. The poor surface obtained during rolling of air melted heats, however, did not result.

The carbonitrides in the grain boundaries of heats melted in air initiated microcracks during creep. This did not occur where the heat was exposed to air after vacuum melting. This was the only factor found to account for the improved ductility of heats exposed to air after vacuum melting. The intragranular oxides and carbonitrides did not initiate microcracks.

Phases Present in M-308 and Super A-286 and Their Relation to Mechanical Properties: *M. Kaufman*, General Electric Co.

Previous work has shown the necessity of information on the distribution and temperature dependence of the phases present in alloys meant for elevated temperature service, especially where the temperature of operation is in a region which affects the phases. The phases and their distribution, together with the grain size at a given temperature, largely determine the mechanical properties of an alloy. Results on two iron-nickel-chromium base alloys, super A286 (V57) and M308, are reported here.

The phases, and their temperature dependence, were determined by X-ray diffraction examination of electrolytically extracted residues from samples with various heat treatments. Metallographic methods were used to determine the phase distribution.

In general, the two alloys have the same basic strengthening phases: Ni_3Ti and M_2Ti. In addition both have Ti(C,N), and super A286 can develop an effective amount of *G* phase. Other phases appear in both alloys in much smaller amounts. The major difference in the action of the Ni_3Ti and M_2Ti in the two alloys is that the phases are dissolved in the super A286 matrix at about 1700°F and 1850°F respectively compared to about 1850°F and 2000°F respectively in the M308. This increased stability immediately indicates that the M308 alloy will retain its mechanical properties to a significantly higher temperature than the super A286.

For both alloys, two *solution* heat treatments had been developed—one for maximum tensile strength and one for maximum stress-rupture life. The maximum tensile strength *solution* treatments for each are actually solution treatments for the Ni_3Ti phase but are precipitation treatments for the M_2Ti phase. The M_2Ti phase (and *G* phase in the super A286) precipitate as fine particles throughout the matrix and/or as occasional coarse particles at the grain boundaries. Subsequent aging leads to precipitation of the Ni_3Ti phase which occurs mainly in the matrix. The coarse M_2Ti (and *G* phase) particles at the boundaries apparently deplete this region of titanium. The combination of M_2Ti and Ni_3Ti dispersed throughtout the matrix leads to high tensile strengths. The maximum rupture life solution treatment does dissolve all the active phases and also may increase the grain size. When aged (at the same temperature as is used with the maximum tensile strength treatment) only Ni_3Ti precipitates. However, it now does form a fine, nearly continuous grain boundary network which, together with the increased grain size, acts to increase rupture life. The strengthening of the matrix obtained is not as great as the condition which has both M_2Ti and Ni_3Ti present in the matrix. (The M_2Ti is considerably harder than Ni_3Ti). Fatigue life suffers concurrently with the production of the continuous grain boundary network.

Growth of Ni$_3$(Al, Ti) Precipitate in a Ni-Cr-Ti-Al Alloy: *N. E. Rogen* and *N. J. Grant*, Massachusetts Institute of Technology.

THURSDAY, FEBRUARY 19, PM

IMD

Research Summaries on Interfaces and Surfaces (IV)

(Based on Submission of Research Abstracts)

2:00 pm St. Francis Hotel Borgia Room

R. Huggins, Chairman

Stress-Corrosion Cracking in Single Crystals of AZ61X Magnesium Alloy: *F. Meller*, Ford Motor Co., and *M. Metzger*, University of Illinois.

Coarse grained specimens and single crystals of solution treated 6Al-1Zn-0.3Mn magnesium alloy were tested in several aqueous environments by stressing stepwise in tension to failure. Strain markings on the electropolished surface were followed during the course of the test and X-ray examination was made before and after testing. In the first group each specimen contained several grains of different orientations; in these, cracking was not observed until one grain had suffered some plastic strain and the crack formed in that grain. Only one failure along the basal plane was noted. The second group consisted of single crystals having basal planes at an intermediate angle to the specimen axis; in these cracking was preceded by basal slip and the crack ran at an angle of 70 to 90° to the basal plane. This non-basal cracking was produced at low tensile stresses, in the range 3500 to 4500 psi. The conditions required for this mode of cracking and the significance of the plastic deformation prior to cracking are discussed. It is postulated that this mode of cracking is inhibited in polycrystalline material and this accounts for the difference between the present observations and those of Priest, Beck and Fontana who noted that failure tended to follow the basal plane in highly stressed polycrystalline specimens of this alloy.

On the Structure and Properties of Bicrystals With Common Lattice Sites: *C. G. Dunn*, General Electric Co.

Since the manner in which recrystallization nuclei form and the rate at which they grow may depend on special relationships with their surroundings, it is important for this reason alone to consider and describe groups of bicrystals having as a variable the number of common lattice sites. Properties such as grain boundary energy and grain boundary diffusion have been measured or calculated for bicrystals having common lattice sites. Opinions have been given on the manner in which common lattice sites may affect the rate of migration of a boundary when a driving force is present. Aust and Rutter have shown from quantitative measurements on boundary migration in zone refined lead that common lattice sites appear to have a strong affect, provided small amounts of tin are added to the lead. Since rate of boundary migration is expected to depend on the volume fraction of common sites, a three dimensional description of the structure is needed.

The present treatment of the structure and the volume fraction of common lattice sites follows that begun by Kromberg and Wilson and extended by Frank. Emphasis, however, is on the BCC lattice. The procedure for obtaining all of the important relationships such as those that can be given in terms of an angle of rotation about a common 110 axis, for example, is formulated and the results expressed by a sequence of decreasing volume fractions. A number of two dimensional models showing the structures are given. Results are correlated with published data for primary recrystallization, grain boundary energy, and grain boundary diffusion.

Grain Boundary Migration in Zone Refined Lead With Small Additions of Tin: A Comparison of Theory and Experiment: *J. W. Rutter* and *K. T. Aust*, General Electric Co.

In a previous experimental study of grain boundary migration in zone refined lead with small tin additions, two types of high-angle boundary were observed. It was found that the speed of migration of the *special* type, which always separates grains having a special relative orientation relationship (rotation of 38° or 22° about a common <111> axis or by 28° about <100>), is relatively little decreased by an increase in tin content in the range 5 to 20 ppm by weight and the activation energy for migration is constant at 6 Kcal per g atom. The *random* type, which separates grains in random relative orientation, shows a migration speed which is relatively sharply decreased by an increase in tin content from less than 1 to 15 ppm and an activation energy which increases from about 15 to 40 Kcal per g atom with increasing tin content in this range.

These quantitative observations are compared with the predictions of various theories of grain boundary migration which, prior to this work, could not be critically evaluated. The following conclusions are reached: 1) The dislocation theory of boundary migration is not applicable to large-angle grain boundaries. 2) The results do not support the *group process* theories of grain boundary migration which suggest that the activation process is the disordering or melting of a group of atoms along the boundary. 3) The very high activation energies frequently observed in recrystallization and grain growth experiments are attributed to the effects of solute impurity atoms. 4) The elementary process of grain boundary migration involves the activation of only one atom, as assumed in the *single-process* theory. This process appears to be similar to that of grain boundary self-diffusion, as suggested by Turnbull. 5) The quantitative predictions of the theory of impurity-controlled boundary migration advanced by Lücke and Detert were not verified.

Orientation Relationships for Grain Boundary Migration in Zone-Refined Lead: *K. T. Aust* and *J. W. Rutter*, General Electric Co.

In previous studies of the growth of recrystallized grains into melt-grown, striated single crystals of zone refined lead, special orientation relationships were frequently observed between the recrystallized grain and the striated crystal into which it grew. However, these special orientation relationships, in which the two crystals were related by rotations of 22° or 38° about a common <111> axis or by 28° about a common <100> axis, were only obtained when the zone refined lead contained 5 to 40 ppm Sn, by weight. With a tin content less than 1 ppm, the orientation relationships were essentially random (16° to 60° about high-index rotation axes). Kinetic data showed that boundaries separating crystals in special orientation relationship have a much higher mobility than other grain boundaries when the tin concentration is in the 5 to 40 ppm range; this difference in mobility becomes small as zero tin concentration is approached.

In order to test the possibility that an insufficient number of nuclei were introduced to allow selective growth to operate in the case of zone refined lead with less than 1 ppm Sn, orientation relationships were determined for recrystallized grains introduced under a variety of conditions. For example, localized deformation at the temperature of liquid nitrogen, followed by growth under various annealing conditions, was employed. In all cases of high-purity material studied, random orientation relationships have been obtained. It is concluded that the presence of solute impurity plays a major role in promoting the development of special orientation relationships.

Results have also been obtained concerning the effect of silver as solute on the rate of grain boundary migration and the development of special orientation relationships in zone refined lead.

The experimental observations are discussed in relation to annealing textures which have been observed in face-centered cubic metals.

Oriented Nucleation and Recrystallization Textures: *J. L. Walter*, General Electric Co.

During the deformation of a metal, regions are formed which upon heating act as centers of recrystallization. From these nuclei new grains form and by growth eventually consume the deformed matrix. The new grains do not have the same orientation as the old deformed grains. This nucleation and growth is called primary recrystallization.

The textures obtained on primary recrystallization are determined by the disposition and growth propensity of the nuclei after deformation. Subsequent texture changes by normal grain growth and discontinuous grain growth are dictated by the textures and structures developed during primary recrystallization. It is of interest

to understand the factors that determine the disposition and growth of nuclei from the deformed matrix. In particular, it is desirable to know whether nuclei of all orientations are present in the matrix or whether they are restricted to certain preferred orientations.

The rolling and annealing textures of (100)[001] single crystals of silicon iron were studied. The crystals were reduced in the range from 65 to 92.5 pct in thickness and annealed at 700 and 1000°C in salt baths. Although the deformation textures differed according to the amount of reduction, the early forming primary recrystallization textures were always a spread (100)[001] type. Weak components of the deformation textures were found in the same orientation as the recrystallization texture, except for samples rolled 92.5 pct. It was concluded that the nuclei for primary recrystallization in this system consisted of areas of the single crystal that had not rotated as far as the major portion of the crystal during deformation. The rate of growth of these nuclei depends on the extent of the deviation from the major part of the deformed and rotated lattice.

Effects of Grain Boundary Structure on Precipitate Morphology in an Fe-Si Alloy: *S. Toney*, General Electric Co., and *H. I. Aaronson*, Ford Motor Co.

Oriented bicrystals of an Fe-1.55 pct Si alloy which could be partially transformed from ferrite to austenite by heating to elevated temperatures were used to examine the effects of grain boundary structure upon the morphology of the austenite crystals nucleated at the boundary.

Most of the bicrystals prepared were of the (110)[001] type, with θ, the angular disorientation of the cube directions, varying between ½° and 44°. One small angle (½° or 1°) and one large angle (22½° or 23°) boundary of each of the following types was also grown: (110)[001], θ = 45°; (100)[001]; and (100)[011]. Isothermal transformation of sections of individual bicrystals was carried out at temperatures between 990 and 1030°C.

In the (110)[001] series of bicrystals, the tendency toward preferential growth along the grain boundary was small when $\theta \leq 6°$. Austenite crystals formed in several morphologies, with idiomorphs (approximately equiaxed crystals) appearing most frequently. At θ = 11°, an increased tendency toward growth along the boundary was observed. Allotriomorphs (crystals which grow primarily along the boundary) were clearly the predominant morphology at larger angle grain boundaries. Similar morphological patterns were observed in the (110)[001], θ = 45° bicrystals and in the larger angle bicrystals of the two (100) series. At the small angle grain boundaries in the (100) series, however, the tendency toward allotriomorphic growth, though smaller than at the large angle boundaries, appeared to be greater than at the small angle boundaries in the (110) series.

The similarity of the orientation dependencies of grain boundary diffusion and austenite morphology in silicon-iron indicates that preferential diffusion along the boundary plays an important role in the formation of allotriomorphs at large angle grain boundaries. At the small angle boundaries, the presence of both edge and screw dislocations in the boundaries of the (100) bicrystals and of primarily edge dislocations in the boundaries of the (110) bicrystals may be responsible for the morphological differences observed.

Transformation Mechanisms in a Hypereutectoid Titanium-Chromium Alloy: *H. I. Aaronson*, Ford Motor Co., *W. B. Triplett*, Carnegie Institute of Technology, and *G. M. Andes*, E. I. du Pont de Nemours and Co., Inc.

The proeutectoid $TiCr_2$ and the eutectoid transformations in a Ti-17.42 pct Cr alloy have been studied metallographically and compared with their counterparts in hypoeutectoid Ti-Cr alloys.

Proeutectoid $TiCr_2$ structures are prominent at temperatures between the transus (790°C) and approximately 650°C. At lower temperatures (through 550°C), the increasingly early intervention of the eutectoid reaction largely confines the proeutectoid reaction to the formation of progressively thinner rows of crystals along the grain boundaries.

Grain boundary allotriomorphs are the dominant proeutectoid morphology throughout the temperature range investigated. Sideplates and intragranular plates form only in small numbers. Idiomorphs appear intragranularly at higher temperatures. Sympathetic nucleation plays only a minor role in the formation of proeutectoid $TiCr_2$ structures. Appreciable variations in $TiCr_2$ morphology frequently develop along even those grain boundaries whose orientation is approximately constant.

The foregoing morphological pattern differs markedly from that of the proeutectoid alpha reaction, in which plates form prolifically, idiomorphs not at all, and allotriomorphs are only a minor component of the microstructure at temperatures more than about 25°C below the transus. The correlation between grain boundary orientation and morphology is much better in the alpha reaction and sympathetic nucleation appears to be responsible for the formation of most of the crystals in the microstructure at some temperatures.

An attempt will be made to provide a basis for understanding the morphological differences between the two proeutectoid transformations, in terms of the effects of the amount of undercooling below the transus on the ratio of the rate of migration of the disordered facets of interphase boundaries to that of facets with dislocation structures.

The eutectoid reaction in Ti-17.42 pct Cr is non-lamellar in character at 675°C (as previously found in hypoeutectoid alloys), but an increasingly prominent lamellar component appears at lower temperatures.

Thermal Etching and Evaporation of Chromium in Hydrogen: *M. J. Fraser*, Westinghouse Electric Corp.

Rolled chromium sheet (99.96+ pct Cr), when heated at elevated temperatures under purified hydrogen (1 atm), undergoes thermal etching and evaporation. Four temperatures, 1100, 1300, 1400, and 1500°C were selected for isothermal anneals and the times ranged from 67 to 24 hr depending on the temperature. The resulting surface structures were studied at room temperature by X-ray, and by optical, interference, and electron microscope techniques.

At 1100°C, generally, only thermal grooves are developed at grain boundary-surface intersections, but at higher temperatures, the surface is striated, leading to various configurations depending on the temperature and the orientation of the particular crystal with respect to the surface. At temperatures above 1100°C, chromium develops {100}, {110}, and {112} facets.

Evaporation occurred by a lamellar mechanism on both the {100} and {110} planes, but significant differences in the lamellae structure were observed. High-amplitude lamellae were noted to be subdivided into units of much lower amplitude. Also, cross facetting was often noted at lamellae edges. Other characteristics of both low and high-amplitude lamellae are reported. The sources of the lamellae, where a well developed lamellar pattern is observed, are grain boundary grooves as well as pit sources within the grains.

Influence of Thermal History on Preferred Orientations in the Recrystallization of Technically Pure Aluminum: *B. G. Liebman*, Brown University.

The influence of the state of impurities (dissolved or precipitated) on the generation of preferred orientations in recrystallization of strained aluminum single crystals has been investigated. The crystals contained 99.97 pct Al, 0.09 pct Fe, 0.09 pct Si and 0.03 pct Zn, only the iron not being well within its solid solubility limit. No preferred orientations were obtained when the crystals were annealed for several hours at 620°C prior to deformation. On reheating at temperatures below 500°C, the yield point of the crystals increased, reached a maximum and finally decreased, a typical behavior correlated to the precipitation of a second phase (iron). Recrystallization produced preferred orientations in samples which were reheated until the maximum yield point was reached or exceeded. This would indicate that iron in supersaturated solid solution prevents the generation of preferred orientations while it has no effect of this kind when precipitated. This effect of the state of impurities explains contradictory results previously obtained by different groups (Graham-Cahn, and Liebmann-Lücke-Masing) investigating growth rates and preferred orientations in the recrystallization of aluminum single crystals.

A possible mechanism for the prevention of preferred orientations by dissolved iron is discussed (based on growth selection and interaction between grain boundaries and foreign atoms).

THURSDAY, FEBRUARY 19, PM

ISD Gas-Metal Research

2:00 pm St. Francis Hotel Georgian Room

F. C. Langenberg and *Bruce Wagner*, Associate Chairmen

T. F. Kaveney, Discussion Leader

Solubility of H and N in Binary Alloys of Fe, Co, Ni: *T. I. Busch* and *R. A. Dodd*, University of Pennsylvania.

Solubility of N in Fe-Mn Alloys: *R. A. Dodd* and *N. A. Gokcen*, University of Pennsylvania.

Hydrogen Solubility in Liquid Iron Alloys: *T. B. King* and *J. Humphries*, Massachusetts Institute of Technology.

N Solubility in Liquid Fe-Ni-Cr Alloys: *J. F. Elliott* and *J. C. Humbert*, Massachusetts Institute of Technology.

THURSDAY, FEBRUARY 19, PM

EMD Chlorination Processes (II)

2:00 pm St. Francis Hotel Colonial Room

R. A. Gustison and *D. H. Baker, Jr.*, Associate Chairmen

Flash Chlorination of Very Finely Divided Metal Oxides: *S. S. Cole* and *L. W. Rowe*, National Lead Co.

A means for the fluosolids chlorination of very finely divided (1-50 micron size) oxides by passage through a restraining bed of coarser material is described. Operating data obtained with a small scale unit are included.

Chlorination of Titanium Slags: *E. C. Perkins, H. Dolezal*, and *R. S. Lang*, U. S. Bureau of Mines.

Titanium slags produced from five domestic ilmenite deposits were evaluated by chlorination in a small continuous moving bed chlorinator. The effect of the slag impurities on efficiencies and operation are discussed.

Use of a Packed Column for Purification of Chlorinated Ilmenite Vapors: *V. A. Nieberlein*, U. S. Bureau of Mines.

Carbon Reactivity as a Factor in the Chlorination of Metallic Oxides: *T. J. McIntosh*, Tennessee Products and Chemical Corp., and *L. W. Coffer*, Battelle Memorial Institute.

The reduction of carbon dioxide by carbon is strongly endothermic and is also a slow reaction. The reactivity of the solid carbon exerts a strong influence on the rate, and the equilibrium of the reaction

$$C + CO_2 = 2CO$$

may not be approached closely in practice.

The above facts, widely applied in other carbothermic processes, are re-examined with respect to chlorination of mixtures of metallic oxides with carbon.

Where a comparatively unreactive carbon is used, reduction of carbon dioxide is suppressed, and some effects to be expected are: (1) heat is conserved; (2) temperature of the system is higher; (3) the main chlorination rate increases; (4) some side reactions may reach significant rates at the higher temperatures; (5) attack on refractories may be more severe; (6) consumption of carbon is less; (7) formation of hydrogen chloride is less.

THURSDAY, FEBRUARY 19, PM

EMD-ISD

Pyrometallurgical Processes

2:00 pm St. Francis Hotel Italian Room

G. H. Turner and *A. C. Richardson*, Associate Chairmen

Selective Smelting of Lateritic Ores by the Strategic-Udy Process: *M. J. Udy* and *M. C. Udy*, Strategic-Udy Processes, Inc.

Ferromanganese From Open Hearth Flush Slags by the Strategic-Udy Process: *M. J. Udy* and *M. C. Udy*, Strategic-Udy Processes, Inc.

Experimental Sintering and Smelting of Low-Grade Siliceous Iron Ore: *G. E. Viens, R. A. Campbell, G. C. Sirianni, G. N. Banks*, and *R. R. Rogers*, Canadian Department of Mines and Technical Surveys.

Use of Fluid Bed Reactors as High-Temperature Condensers: *L. W. Coffer* and *F. M. Stephens, Jr.*, Battelle Memorial Institute.

Chemical Oxidation of Carbon by Lead Silicate Slags: *D. K. Jena* and *C. S. Samis*, University of British Columbia.

Reduction of the Iron Values of Ilmenite to Metallic Iron at Less Than Slagging Temperatures: *R. H. Walsh, H. W. Hockin, D. R. Brandt, P. L. Dietz*, and *P. R. Girardot*, Columbia-Southern Chemical Corp.

THURSDAY, FEBRUARY 19, PM

EMD-MBD

Chemical Processes—Uranium

2:00 pm Sheraton-Palace Hotel Comstock Room

R. D. MacDonald and *Bruce Clemmer*, Associate Chairmen

Leaching, Ion Exchange, and Precipitation of Blind River Uranium Ores: *R. P. Ehrlich, K. D. Hester*, and *A. G. Roach*, Rio Tinto Management Services, Canada.

Kinetic Study of the Dissolution of UO_2 in H_2SO_4: *T. L. Mackay* and *M. E. Wadsworth*, University of Utah.

Working the Kinks Out of the Homestake-New Mexico Partners Mill: *C. W. Garman*, Homestake-New Mexico Partners.

Union Carbide's Uranium Operation at Maybell, Colorado: *K. W. Lentz*, Trace Elements Corp., Unit of Union Carbide Corp.

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To be successful, your program for professional and personal development must include active support of the professional society for metals men. Most professional metals men are identified by their membership in The Metallurgical Society of AIME. Through activities such as the Annual Meeting they take advantage of the existence of a formal organization dedicated to advancing their interests and those of the metals industries.

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METALLURGICAL SOCIETY OF AIME

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COMING EVENTS

March 16-20, Western Metal Exposition and Congress, Pan-Pacific Auditorium and Ambassador Hotel, Los Angeles.

April 2-3, AIME Physical Metallurgy of Stress Corrosion Fracture Conference, Mellon Institute, Pittsburgh.

Apr. 5-10, Fifth Nuclear Congress, Cleveland Auditorium, Cleveland.

Apr. 6-8, AIME 42nd National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Jefferson Hotel, St. Louis, Mo.

Apr. 16-18, Northwest Regional Conference, Olympic Hotel, Seattle, Wash.

Apr. 27-30, AIME International Symposium on Physical Chemistry of Extractive Metallurgy, Penn-Sheraton Hotel, Pittsburgh.

May 21-22, AIME New England Regional Conference, Statler Hotel, Hartford, Conn.

Aug. 31-Sept. 2, AIME Conference on Semi-conductors, Statler Hotel, Boston.

Nov. 2-6, Fall Meeting of the Metallurgical Society of AIME, Morrison Hotel, Chicago.

Dec. 2-4, AIME 17th Electric Furnace Conference, Cleveland Hotel, Cleveland.

Feb. 14 18, 1960, AIME New York Section, **Annual Meeting,** Hotel Statler, New York.

Apr. 4-6, 1960 AIME Chicago Section, **Blast Furnace & Open Hearth Conference,** Palmer House, Chicago.

June 13-15, 1960, first **International Powder Metallurgy Conference,** Hotel Biltmore, New York, under joint auspices of AIME and MPA.

Nov. 30-Dec. 2, 1960, 18th Electric Furnace Steel Conference, Morrison Hotel, Chicago, Ill.

COMING EVENTS

Jan. 15, AIME Utah Section, speaker: Harold Wright, *Rubber and Plastic as Cost Savers in Metallurgical Installations*. Mr. Wright is executive vice-president of Galigher Co.

Jan. 21, AIME Symposium on Mechanical Working of Steel, Del Prado Hotel, Chicago.

Feb. 5, AIME New York Powder Metallurgy Group, Brass Rail Restaurant, New York City.

Feb. 13, AIME Southwestern Local Section, Winter meeting, St. Louis, Mo.

Feb. 15-19, AIME Annual Meeting, St. Francis Hotel, Sheraton-Palace Hotel, and Sir Francis Drake Hotel, San Francisco.

Mar. 12, AIME, NOHC Northern Ohio Local Section, Annual technical meeting, Pick-Ohio Hotel, Youngstown, Ohio.

Mar. 16-20, Western Metal Exposition and Congress, Pan-Pacific Auditorium, Los Angeles, Calif.

Apr. 2-3, AIME Technical Conference on Stress Corrosion Fracture, Mellon Institute, Pittsburgh.

Apr. 5-10, Fifth Nuclear Congress, Cleveland Auditorium, Cleveland.

Apr. 6-8, AIME 42nd National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Jefferson Hotel, St. Louis.

Apr. 16-18, AIME Northwest Regional Conference, Olympic Hotel, Seattle, Wash.

Apr. 22-26, AIME Florida Section, Annual spring meeting of the Metal Treating Institute, Hollywood Beach Hotel, Hollywood, Florida.

Apr. 27-30, AIME International Symposium on the Physical Chemistry of Process Metallurgy, Penn-Sheraton Hotel, Pittsburgh.

May 4, AIME, NOHC Chicago Local Section, Spring Meeting at Phil Smidt's Restaurant, Chicago.

May 21-22, AIME New England Regional Conference, Statler Hotel, Hartford, Conn.

June 5, AIME, NOHC Southern Ohio Section, Golf Outing, Summit Hills Country Club, Fort Mitchell, Kenton County, Ky.

Dec. 2-4, AIME Cleveland Section, 17th Electric Furnace Steel Conference, Hotel Cleveland, Cleveland, Ohio.

Feb. 14-18, 1960, AIME New York Section, Annual Meeting, Hotel McAlpin and Hotel Statler, New York.

Apr. 4-6, 1960, AIME 43rd National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Palmer House, Chicago.

Sept. 27-30, 1960, AIME Cleveland Section, the Iron and Steel Exposition of the Association of Iron and Steel Engineers, Cleveland Public Auditorium, Cleveland.

June 13-15, 1960, first International Powder Metallurgy Conference, Hotel Biltmore, New York, under joint auspices of AIME and MPI.

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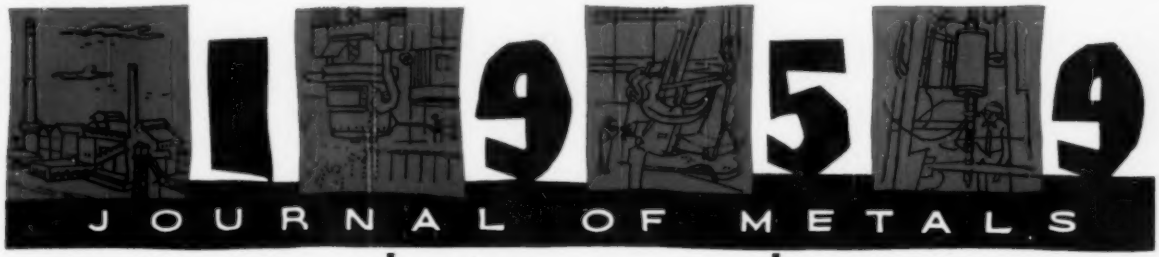

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